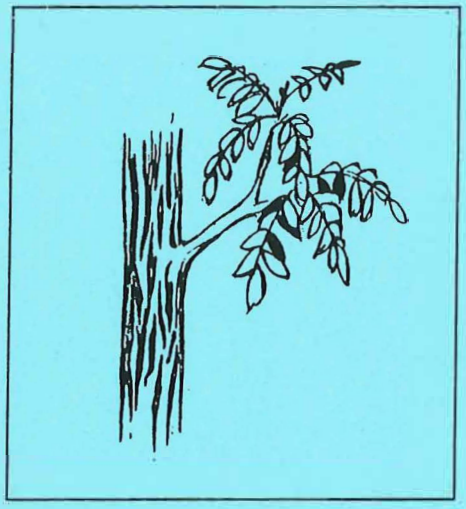

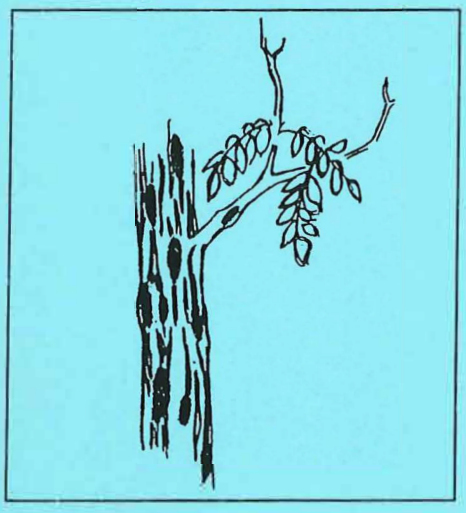

FOREST HEALTH CONDITIONS IN WISCONSIN

ANNUAL REPORT 1997

Wisconsin Department of
Natural Resources
PO Box 7921
Madison, WI 53707

FOREST HEALTH CONDITIONS IN WISCONSIN

CALENDAR YEAR 1997

[1]

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WISCONSIN DEPARTMENT OF NATURAL RESOURCES

FOREST HEALTH PROTECTION UNIT

[1] Illustrations of butternut canker on front cover and this page by David Kopitzke, Landowner Contact Specialist, Bureau of Endangered Resources, Wisconsin Department of Natural Resources.

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INTRODUCTION

Changes in the forest insect and disease program

This was a year of change for the forest pest program. We believe these changes will better reflect what we do and improve our level of service.

- New Name! The Forest Pest Program is now the **Forest Health Protection** Program.
- New Personnel! **Kyoko Shimizu** was hired as a forest pathologist and is stationed in Rhinelander.
- New Territories! Reorganization within the DNR has initiated changes in the territories covered by forest health specialists. Their territories are shown in Figure 1.

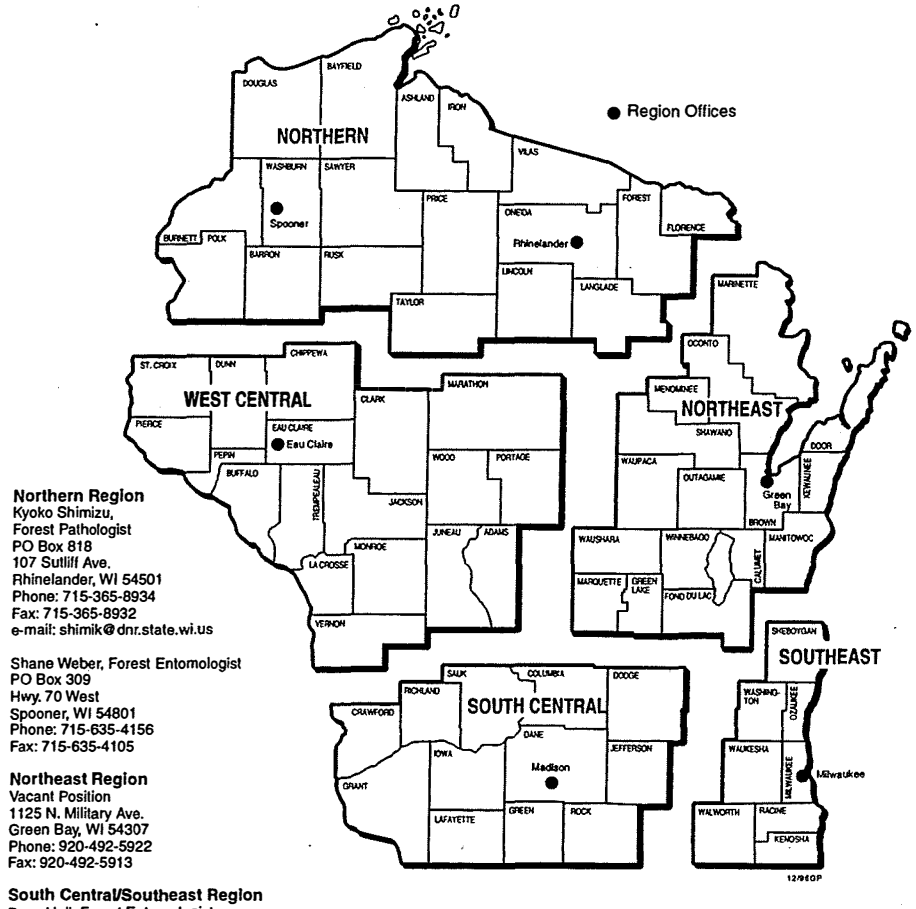

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Figure 1. Location of forest pest specialists and the territories they cover – December, 1997.

Changes in the format of this report.

The recent availability of Forest Inventory and Analysis (FIA) data prompted the forest health protection unit to redesign the format of its report. Efforts were made to integrate forest health surveys, observations and special report data with pertinent FIA data. We believe this gives the reader a more relevant picture of the importance of various insects, diseases and other disturbance agents on the health of the forest.

The new format of this report includes:

- **1997 Forest Health Highlights Wisconsin** – a summary of major forest health problems in Wisconsin as posted on the World Wide Web.
- **Alerts** - a list and description of insects and diseases that are new or of special interest.
- **Recent Publications Available to Order** - a list of new publications (within the last 5 years) that are available by ordering through the forest health protection unit.
- **The Resource** - a section that outlines pertinent information on the forest resource. Data from this section comes from the FIA survey.
- **Habitat Types** - an introduction to the habitat type concept and its relevance to forest insects, diseases and other disturbance agents.
- **Selected Timber Types** - an overview of selected timber types including current inventory data, historical and current information relevant to forest insects, diseases and other disturbance agents. Where possible, projections were made regarding the future impacts of selected insects and diseases.
- **Summary of Other Pests Reported** - a list of pests observed throughout the state in 1997.
- **Special Project Summaries** - summaries and updates of special projects including surveys and cooperative projects with various researchers.

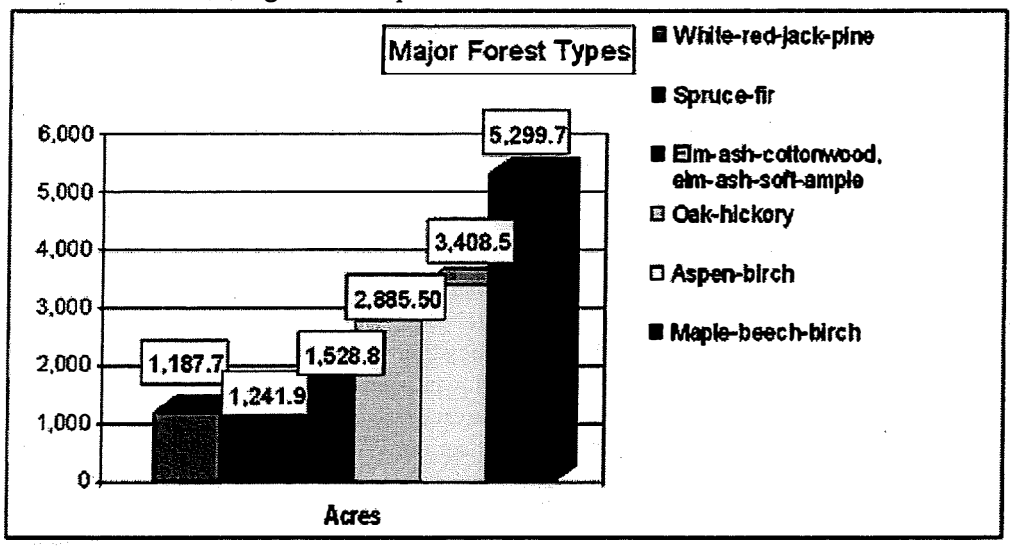
Reprinted from the World Wide Web
(http://willow.ncfes.umn.edu/fhh-97/wi_97.htm)

1997 Forest Health Highlights
Wisconsin

The Resource

The area of forest land in Wisconsin has been steadily increasing in recent decades and currently stands at 16.0 million acres, representing 46 percent of the total land area. Wisconsin's forests are predominately hardwoods, with 84 percent of the total timberland area classified as hardwood forest types. The primary hardwood forest type in the state is maple-beech-birch, which makes up 5.3 million acres.

Forests are important to the economy of Wisconsin, not only in the form of wood products but also in the form of recreation and tourism. The primary and secondary wood products industry is the second largest employer in the state and puts Wisconsin first in the nation in the production of fine paper, sanitary paper products, children's furniture, and millwork. The value of shipment of these products annually exceeds $19.7 billion. Forest and water resources in Wisconsin are a primary tourism attraction for both residents and visitors. The variety of Wisconsin's forest ecosystems support a great diversity of wildlife species, while recreational use of the forests continues to grow and expand.



Special Issues

In 1997, insect and disease detection surveys were conducted on approximately 5.5 million acres and evaluation surveys on 3.8 million acres. In addition, Wisconsin DNR regional forest pest specialists continued to teach integrated pest management principles to Wisconsin DNR foresters, industrial foresters, and private woodland owners. Regional forest pest specialists and forest pest unit staff provided a wide variety of programs and information on forest pests in 1997. Approximately 3,800 individuals were educated at 70 different training sessions.

Wisconsin recorded its first visible **gypsy moth** defoliation in 1997. A two-acre patch of willow and aspen in Oconto County was completely defoliated; surrounding willows were lightly defoliated. In mid July, 5th and 6th instar caterpillars were massed on trunks of partially defoliated trees. Some of the caterpillars exhibited symptoms of the gypsy moth nucleopolyhedrosis virus (NPV); presence of the virus was confirmed by lab analysis.

In the spray program, 40,520 acres in 24 locations in 13 counties were sprayed twice with 36 BIU of *Bacillus thuringiensis* var. kurstakii, by fixed wing aircraft. Trapping results indicated that the spraying was successful in reducing numbers in the spray blocks.

The entire state was trapped in a grid of over 55,000 delta pheromone traps this year. Adult males were caught in every county and a preliminary survey of traps as of November 15, 1997 revealed a total of 91,491 moths collected throughout the state. During the trapping period, egg masses, larvae, pupae, or adult females were found in over 100 locations. The formal egg mass survey began in mid October and will continue through 1998.

During the field season of 1997, the fungus *Entomaphaga maimaiga,* the larval parasite *Cotesia melanoscela,*

and the egg parasitoid *Ooencyrtus kuvanae* were introduced as a means of biocontrol for gypsy moth in Wisconsin. Soil containing spores of *E. maimaiga* were released in 32 locations in eastern Wisconsin. Gypsy moth larvae from these populations will be collected in June of 1998 and reared to determine if they have become infected with the fungus. Cocoons containing pupae of *C. melanoscela* were introduced into three sites in Brown, Manitowoc, and Oconto counties. The sites will be revisited next June to determine how many adult parasites successfully emerged. Gypsy moth larvae from these sites will also be reared to determine if they have become parasitized. *O. kuvanae* was released in several locations in Door, Manitowoc, and Oconto counties. A follow-up survey conducted to look for current gypsy moth egg masses that showed signs of *O. kuvanae* emergence yielded negative results.

Extremely **high winds** blew through the Menominee Indian Reservation in Menominee County on July 16, 1997. The storm path was a corridor approximately three miles wide and 12 miles long running almost directly north to south across the entire reservation. Winds were estimated to be in excess of 80 mph in the worst hit parts of this corridor.

The forest lands were the most seriously affected parts of the reservation. It is estimated that 21,000 acres were affected by the storm, with 3,000+ acres having actual damage ranging from scattered fallen trees to nearly complete blow down. White pine shelterwood cuts in the southern part of the reservation bore the brunt of the damage, with over 75% of the seed trees snapped off or tipped over in the hardest hit areas. Some prime sawtimber hardwood areas just north of the reservation also incurred extremely heavy damage. Estimates of blow down are over 30,000,000 board feet.

Northwestern Wisconsin saw a resurgence of the **jack pine budworm** this year. Defoliation occurred in four northwestern counties covering about 120,000 acres, with Douglas County receiving the bulk of the damage. Most of the defoliation was no more than moderate in intensity and caused little significant damage. However, scattered pockets of heavy defoliation covered close to 10,000 acres. In these areas topkill was prevalent and tree mortality was not uncommon. Egg mass survey results indicate that these areas will start the 1998 growing season with slightly fewer budworms than in 1997.

Butternut canker is a devastating fungus disease of butternut. In Wisconsin, butternut canker has been reported in 48 of the 62 counties where butternut trees occur. This disease has been observed on 91% of the butternuts surveyed in 79 locations throughout Wisconsin.

Collections of butternut scion wood were expanded to three new locations where apparently disease resistant trees are growing in Menominee, Waupaca, and Winnebago counties. Scion wood is grafted onto black walnut root stock and planted in orchards in an effort to preserve and maintain potentially resistant trees. This is a cooperative project with the USDA Forest Service, North Central Experiment Station.

A survey of members of the Wisconsin Woodland Owners Association was conducted to locate potentially disease resistant butternut trees and to initiate a network of landowners interested in butternut. Results of the survey will be summarized in the Wisconsin annual report of forest pest conditions.

Oak wilt, a fungus disease of oaks, continues to be of major concern in Wisconsin's rural and urban forests, especially in the southern two-thirds of the state. Oak wilt is now present in 51 of Wisconsin's 72 counties; no new counties reported the presence of oak wilt this year. Recent efforts to control this disease have concentrated in two areas: 1) formation of a committee (associated with the WI Arborists Association) that concentrates efforts on information and education in communities, and 2) surveying areas pruned by two electric utilities in an effort to monitor the effects of various pruning practices on the overland spread of oak wilt (1997 is the third year of this survey and it will continue for two more). Three years of survey data support the current pruning practices of these utilities as being effective in minimizing the chance of overland spread of oak wilt. Current guidelines for electric utilities state, in rural areas only, pruning of oak may be conducted from April 15 to July 1, but pruning wounds must be covered immediately with a wound dressing. The guidelines also state that pruning may be conducted in urban and rural areas after July 1 and no wound dressing is required.

A workshop on the current status, biology, and management of oak wilt was conducted in cooperation with the WI Arborists Association. The workshop concentrated on disease management options in the urban setting. Approximately 60 arborists attended.

Other Issues

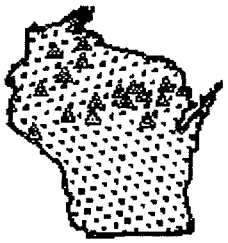
Defoliation by the **cherry scallop shell moth** (*Hydria prunivorata*) increased in Portage and Sauk counties, where trees of all ages were completely brown in mid summer. Most of the defoliated trees refoliated and no mortality was observed during the outbreak. This pest was also found widespread in the west central region of the state where Adams, Jackson, Juneau, Monroe, and Wood counties were heavily affected.

White oak was lightly to heavily damaged by **oak tatters** for the second year in a row. Heavy defoliation to individual trees and groups of trees was noted in many locations throughout southern Wisconsin. Oak tatters is caused by an undetermined spring weather phenomenon. Some specialists believe that the injury is caused by cold temperatures after the bud has broken dormancy, but before it opens. When the leaves open, the tissue

between the veins is missing, giving the leaves a "tattered" appearance.
The **pecan leaf casebearer** (*Acrobasis juglandis*) and another **shoot borer** (*Acrobasis juglanivorella*) erupted in 1997 to cause extremely heavy damage to young black walnut in scattered locations throughout southern Wisconsin. Both species mine the buds shortly after bud break in the spring. The shoot borer causes further damage by mining out new shoots. The casebearer spins a cigar-shaped case between two leaflets where it feeds on a small amount of foliage. A five-year-old plantation in Washington County was stripped of nearly all new growth this year. New buds then formed and the damaged trees produced a light second flush of foliage. In Richland County 15-year-old trees were also nearly stripped of all new growth. Damage was more severe on hill tops and less severe on the lower ground. The heavily damaged trees produced a second flush of foliage.
The **red pine shoot moth** (*Dioryctria resinosella*) normally attacks windbreaks and edge trees of red pine plantations, as it has been doing throughout the west central region this year. In the Central Sands counties it appears to have increased in numbers to its outbreak level for the first time since the early 1980's. The uppermost shoots of interior trees have been heavily attacked, and if this continues for several years, as it has in previous outbreaks, the main stem of sapling and pole-sized red pines may become deformed.
Greenstriped mapleworm (*Dryocampa rubicunda*) caused severe defoliation of red maple on over 5,000 acres in Sawyer and Washburn counties. It also completely stripped 30 acres of silver maple in Interstate Park in Polk County. Since the affected trees did not attempt to reflush, they are expected to recover well in 1998.

Regional Issues

Efforts to detect changes in forest health on a regional (Lake States) basis continues through data collection on permanent plots - 89 for Forest Health Monitoring (FHM) and 18 for North American Maple Project (NAMP). In addition to visiting all plots on the ground, all 18 NAMP plots were observed from the air in an attempt to detect major outbreaks of spring defoliators. No widespread defoliation of sugar maple was detected in 1997. Data for both of these plot programs centers on monitoring crown conditions, including dieback, foliage transparency, and crown density.



▪ Forest Health Monitoring plots
▲ NAMP plots

The regional forest entomologist position in Green Bay is vacant due to the transfer of Andrea Diss to the new Gypsy Moth Coordinator position in Madison. Plans are under way to fill the position as soon as possible. Kyoko Shimizu, plant pathologist, has joined the staff as the forest pest specialist in Rhinelander.
Forest health remained stable based on data on crown conditions and damage assessments from the 89 **forest health monitoring** plots in Wisconsin. The Wisconsin Department of Natural Resources, in cooperation with the USDA Forest Service and the Lumberjack Resource Conservation and Development, monitored forest health throughout Wisconsin. This is Wisconsin's third year in this program designed to monitor the current health and changes in forest health on a regional basis.
The Wisconsin Department of Natural Resources is a participant in the international **North American Maple Project** (NAMP) designed to evaluate the health of sugar maple forests. This project grew out of a concern that sugar maple decline and mortality was affecting the overall health of sugar maple and threatening the maple syrup producing industry. A total of 18 plots have been established in Wisconsin and trees are evaluated annually. Results indicate that sugar maples are in good condition and have recovered from the 1988 and '89 drought.

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February 1997

ALERTS

Forest insects and diseases that are new or of special interest. If you observe any of these, please contact your local forest pest specialist.

White Pine Root Decline - *Leptographium* sp.

Although the fungus *Leptographium procerum* (Kendrick) M. J. Wingfield is well known to be associated with dying white pine in the eastern United States, its role in Wisconsin is unknown. In 1997, a *Leptographium* sp. was isolated from the roots of dying white pine Christmas trees in Richland County. The landowner reported observing chlorosis and browning of foliage on a few scattered trees in 1994; in 1995 - '97, the landowner observed trees dying at an accelerated rate. Mortality associated with *Leptographium* often occurs on sites with a high clay content and poor water drainage. The site in Richland County fits this description and had standing water during periods of high rainfall in 1993. Symptoms of this disease include chocolate brown discoloration of infected roots and the root collar region. Infected areas are likely to be resin soaked. Foliage of infected trees turns yellow then brown. It may take 2 years for a 5-7 year-old tree to die. White pine growing on sites with a high clay content are most vulnerable.

Debate in the scientific community has this fungus categorized as either a pathogen, killing white pine or an opportunist, invading trees under stress. In Wisconsin, *Leptographium* spp. have been isolated from the roots of red pine and from a variety of insects that feed on the lower stem and roots of red pine. It is possible that insects, infested with this fungus, could feed on stressed white pine and transmit the fungus.
**An informational handout on White Pine Root Decline is available and can be ordered. See "Recent Publications" section.*

Annosum Root Rot - *Heterobasidion annosum* (Fr.; Fr.) Bref. (syn. *Fomes annosus* (Fr.; Fr.) (Cooke)

Although not new to the state of Wisconsin, this root rot fungus deserves attention and continued survey efforts. First observed in Wisconsin in 1993 by Dr. Glen Stanosz, *H. annosum* is known to occur in two red pine plantations, one in Adams County and one in Iowa County. The Adams County site is visited annually and disease progress is documented. As has been reported in the literature, disease progress is very slow with only 1-2 trees dying each year. In 1996, an extensive survey of ten red pine plantations was conducted in central and western Wisconsin. Survey sites were selected based on the presence of above-ground symptoms resembling those caused by root rot. No *H. annosum* was detected on any of the ten sites surveyed. Forest pest specialists are on the lookout for this fungus and would appreciate any reports of potential *H. annosum*-infested sites.
**An informational handout on this root rot is available and can be ordered. See "New Publications" section.*

Balsam Fir Needlecast - *Lirula mirabilis* (Darker) Darker & *L. nervata* (Darker) Darker

Reports of these needlecast-fungi in Wisconsin's balsam fir go back as far as the mid-1960's, yet they have been "sleeping" for nearly 3 decades. The population exploded in 1994, probably as a result of the very wet summer of 1993. Normally only an aesthetic problem in natural stands, these fungi can cause dramatic needle browning and loss of 2-3-year old needles on balsam fir Christmas trees. Since 1994, dozens of reports and samples have flowed into the forest health protection lab. These fungi are now known to be widespread throughout northern Wisconsin infecting both wild balsam fir and balsam fir Christmas trees.
**An informational handout on this needlecast is available and can be ordered. See "New Publications" section.*

Yellowing and Necrosis of Balsam Fir Needles - Unknown

Another scourge to balsam fir Christmas trees occurred during the late summer and fall of 1997. In mid-summer, scattered needles turned bright yellow, progressed to brown, then cast. By harvest time, affected needles were cast. No insects, pathogens or other know agents were found associated with this. The only extraordinary condition associated with this phenomenon was the long, cool, and wet late summer and fall weather.

Terminal-Shoot Curl and Mortality of Fraser Fir - Unknown

Samples of Fraser fir Christmas trees' terminal shoots from central Wisconsin and the Lower Peninsula of Michigan were received by the forest health protection unit in 1997. Symptoms included a curled shoot with a sunken "canker-like" area near the base of the shoot. Isolations revealed a secondary fungus (*Alternaria sp*), widely present in the shoots from both states. Alternaria is suspected as only being an opportunist and not a pathogen in this case. No other factors were found to be involved in this problem. Observations and isolations will continue in 1998.

Short-Needle Disease of Scotch pine - Eriophyid mite

Scotch pine Christmas trees in central Wisconsin exhibited symptoms in 1996 and '97, of a new phenomenon: short-needle disease. Symptoms include a premature cessation of needle growth. Affected needles are scattered throughout the developing shoot, leaving a very odd-looking complement of needles. An Eriophyid mite can be observed feeding at the base of affected needle, early in the growing season, just as the shoots are elongating.

RECENT PUBLICATIONS

(To order: tear out this page, mark those publications you would like and send to: Jane Cummings Carlson, DNR Forest Health Protection, 3911 Fish Hatchery Road, Madison, WI 53711, FAX (608) 275-3236, or Email: cummij@dnr.state.wi.us)

_____***Butternut - strategies for managing a threatened tree.*** Ostry, M. E., M. E. Mielke, and D. D. Skilling. 1994. USDA Forest Service, NC For. Exp. Sta., NE Area S&PF, Gen. Tech. Rep. NC-165, 7pp.

_____***Herbicides for forest management 1998.*** Hall, D. and Martin, J. 1998. University of WI Extension, Forestry Facts No. 76, 7 pp.

_____***How to identify and manage needlecast diseases on balsam fir.*** Albers, M., J. Albers, J. Cummings Carlson, L. Haugen, and N. Wenner. 1996. USDA Forest Service, NE Area S&PF, NA-FR-02-96, 9 pp.

_____***How to identify butternut canker and manage butternut trees***. Ostry, M. E., M. E. Mielke, and R. L. Anderson. 1996. USDA Forest Service, NC For. Exp. Sta., NE Area S&PF, Region 8, HT-70, 8 pp.

_____***How to manage eastern white pine to minimize damage from blister rust and white pine weevil***. Katovich, S. and M. Mielke. 1993. USDA Forest Service, NE Area S&PF, NA-FR-01-93, 14 pp.

_____***How to manage jack pine to reduce damage from jack pine budworm***. McCullough, D. G., S. Katovich, R. L. Heyd, and S. Weber. 1994. USDA Forest Service, NE Area S&PF, NA-FR-01-94, 10 pp.

_____***How to prune trees.*** Bedker, P. J., J. G. O'Brien, and M. E. Mielke. 1995. USDA Forest Service, NE Area S&PF, NA-FR-01-95, 30 pp.

_____***Is the forest healthy?*** Stoyenoff, J., J. Witter, and B. Leutscher. 1997. USDA Forest Service, NC Region, 9 pp.

_____***Lake states woodlands: Oak wilt management - what are the options?*** Cummings Carlson, J. and A. J. Martin. 1996. University of WI Extension, Pub. No. G3590, 6 pp.

_____***New introduction - common pine shoot beetle,*** **Tomicus piniperda *(L.).*** Haack, B. and D. Kucera. 1993. USDA Forest Service, NE Area, Pest Alert # NA-TP-05-93, 2 pp.

_____***Oak wilt - Guidelines for minimizing its spread.*** Cummings Carlson, J. 1997.

_____ ***Oak Wilt in Wisconsin: Biology and management***. Cummings Carlson, J. 1997. WI DNR, Forest Health Protection, and Madison Gas & Electric, MGE00035 R1/97.

_____ ***Pear thrips on forest trees***. USDA Forest Service, NE Area, Pest Alert # NA-FB/P-34, 1 pp.

_____ ***Survey to assess the health of sugar maple and other norhtern hardwoods across a pH gradient in Wisconsin, 1987-1988.*** Mielke, M. E., C. L. Rezabek, J. Cummings Carlson, A. J. R. Gillespie. 1991. USDA Foresrt Service S&PF and WI DNR, Bureaus of Air management and Forestry. Publ. No. AM-052 91.

_____ ***A tatum guide to compartmentalization of decay in trees.*** Cummings Carlson, J. 1998. WI DNR, Forest Health Protection, Decay -1998-1, 2 pp.

_____ ***A tatum guide to cankers and canker rots***. Shimizu, K. 1998. WI DNR, Forest Health Protection, Decay-1998-2, 2 pp.

_____ ***Are you thinking of building on a wooded lot?*** WI DNR PUB-FR 12797 (Contains information on oak wilt prevention and management; written by C. Widstrand).

THE RESOURCE

Proportions of Forest Land and Timberland (1996 Forest Inventory Data)

The area of forest land in Wisconsin has been steadily increasing in recent decades and currently stands at almost 16.0 million acres, representing 46 percent of the total land area. The state now has the most forest land than it has had at any time since the first forest inventory in 1936. Wisconsin's forests are predominately hardwoods, with 84 percent of the total timberland area classified as hardwood forest types. The primary hardwood forest type in the state is maple-basswood, which makes up 5.3 million acres (34%) of Wisconsin's timberland area. Conifer types represent 16 percent of the total timberland area (pine forests - 8%, spruce-fir - 6%, and swamp conifers - 2%).

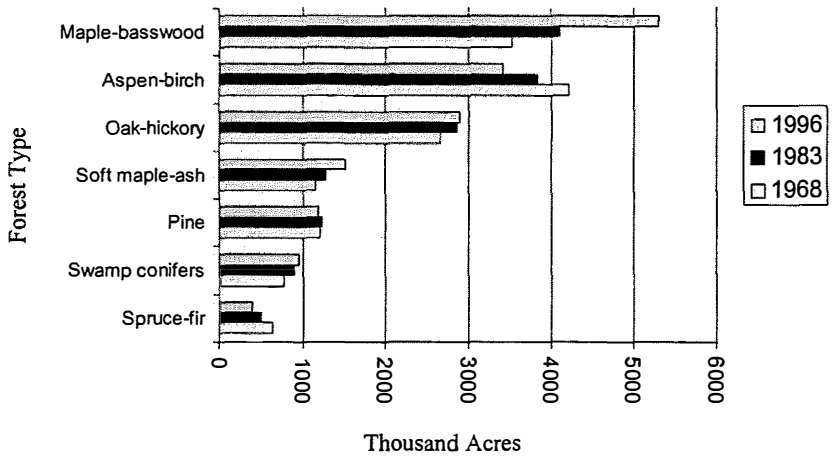


Figure 2. Area of timberland (in thousand acres) by forest type for 1983 and 1996. Data taken from 1996 FIA survey.

Wisconsin timberland increased by 940,000 acres between 1983 and 1996.

- 1968 - 14.54 million acres
- 1983 - 14.76 million acres
- 1996 - 15.70 million acres

Timberland is defined as forest land that is producing, or is capable of producing, more than 20 cubic feet per acre per year of industrial wood crops under natural conditions, that is not withdrawn from timber utilization, and that is not associated with urban or rural development.

Ownership of Wisconsin's Timberland

Individual private landowners are the largest group of timberland owners in Wisconsin, owning 57 percent of all timberland in 1996. Counties and municipalities are the largest group of public owners, holding 15 percent of the total area of timberland in Wisconsin. The percentages of ownership have remained relatively constant since the forest inventory in 1956.

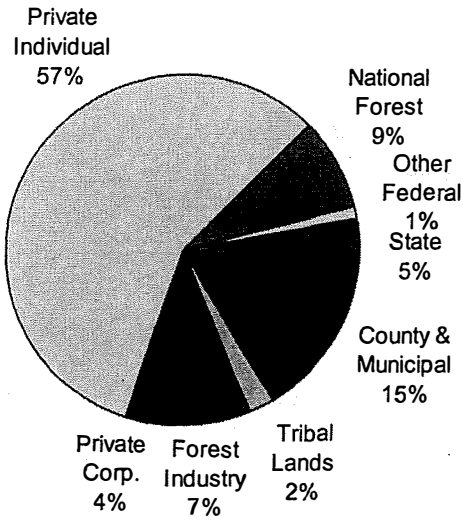


Figure 3. Ownership of Wisconsin's forests. Data taken from 1996 FIA survey.

Growing-stock Volume of Wisconsin's Timberland

Growing-stock volume on timberland in Wisconsin increased from 16.5 billion cubic feet in 1983 to 18.5 billion cubic feet in 1996, reflecting an increase in both area and stocking during the 13 years between inventories. In both 1983 and 1996, hardwoods accounted for ¾ of all growing-stock volume. The species groups with the most growing-stock were aspen, red oak, hard maple, and soft maple. The conifer species groups with the most growing-stock in 1996 were red pine and white pine.

Most Common Species Groups of Wisconsin's Timberland

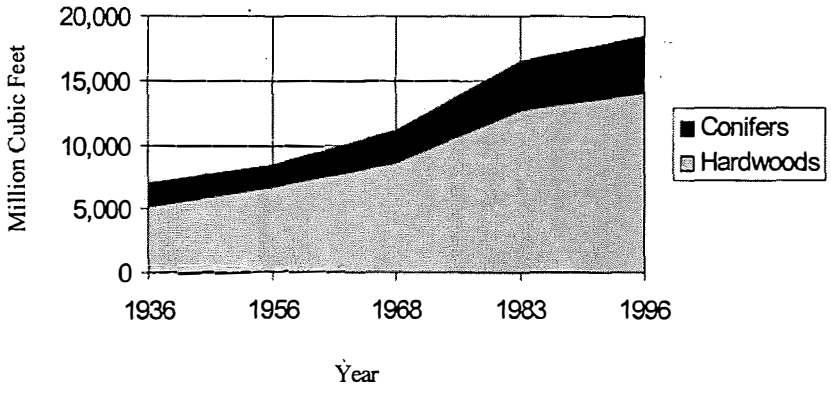


Figure 4. Growing stock volume (in million cubic feet) on timberland in Wisconsin, 1936-1996. Data taken from 1996 FIA survey.

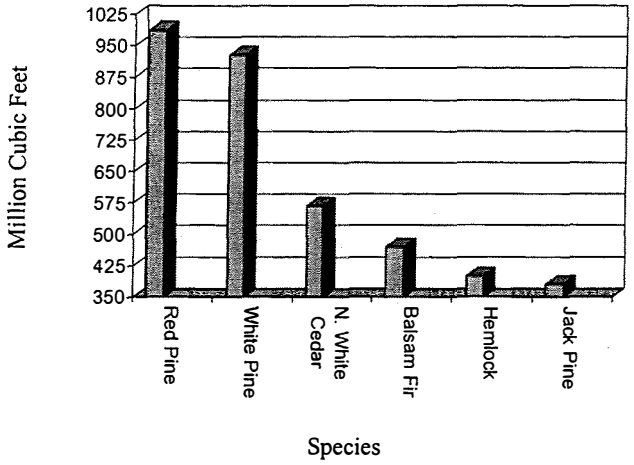


Figure 5. Most common conifer species (in million cubic feet)on timberland in Wisconsin. Data taken from 1996 FIA survey.

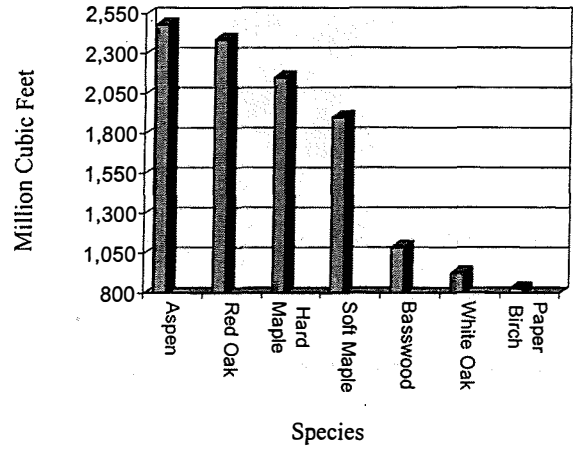


Figure 6. Most common hardwood species (in million cubic feet) on timberland in Wisconsin. Data taken from 1996 FIA survey.

HABITAT TYPES

The Wisconsin Forest Habitat Type Classification System (Kotar *et al.* 1988, Kotar and Burger 1996) is a method of site classification that uses floristic composition, particularly understory species, as an indicator of biological site capability. Knowledge of the biological potential of forest sites can lead to improved management. For convenience, the 95 habitat types recognized in Wisconsin are grouped into 15 habitat type groups - seven northern and eight southern (Figure 7). The groups represent steps of the moisture-nutrient gradient for each of the two regions.

In 1996, the greatest number of acres of forest land was classified into the habitat type groups of: north mesic (2.3 million acres), north wet-mesic (2.2 million acres), and north wet (2 million acres). In general, the pine forest type is primarily represented by dry habitat type groups, other softwoods by mesic to wet habitat type groups, soft hardwoods by mesic to wet-mesic habitat type groups, and hard hardwoods by dry-mesic to mesic habitat type groups.

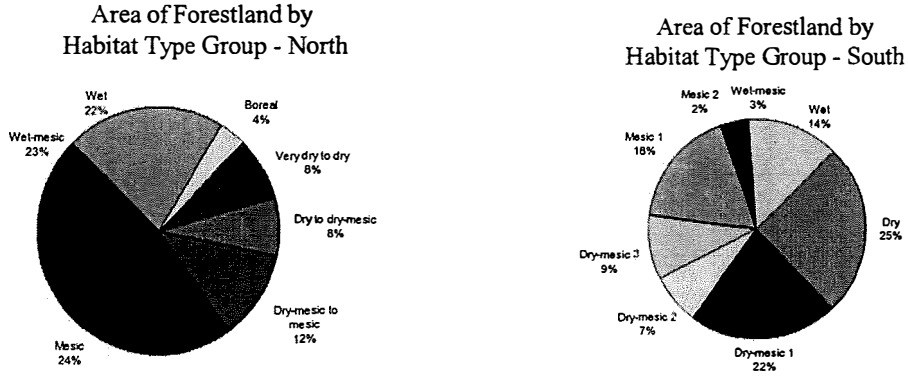


Figure 7. Area of forest land by habitat type group in northern and southern Wisconsin. Data from FIA survey, 1996.

The Link Between Habitat Type, Silviculture and Pest Management

The habitat type system is a valuable tool that provides key information and an ecological framework for decision making. Benefits of using the habitat type system include the following:

1.) It provides a common language that individuals with various levels of knowledge and understanding of ecological principles can use to communicate about the forest resource and management options.

2.) It provides a systematic framework for research and survey projects.

3.) It gives us the opportunity to provide management options based on a site's ecological potential.

Impacts of forest insects, diseases and other disturbances are altered or mitigated primarily through the use of silviculture. Silvicultural options, based on knowledge of habitat type and a site's ecological potential, can provide sound alternatives for growing a healthy forest. Weaving knowledge of biology, epidemiology and history of forest insects, diseases and other disturbances into the decision-making process, will improve the knowledge-base for this process and increase a landowner's potential for making the best management decision.

Currently, the forest health protection program unit is concentrating on developing a forest management decision key for selected timber types, based on habitat type, silviculture and knowledge of the disturbance agent. This type of information will be presented in future annual reports. References to habitat type will also become more common as we collect habitat type data on our pest surveys.

LITERATURE CITED:

Kotar, J., J. Kovach and C. Locey, 1988. *Field Guide to Forest Habitat Types of Northern Wisconsin.* University of Wisconsin-Madison, Department of Forestry and Wisconsin Department of Natural Resources, Madison, 216Pp.

Kotar, J., and T. Burger, 1996. A Guide to Forest Communities and Habitat Types of Central and Southern Wisconsin. Published by The Department of Forest Ecology and Management, University of Wisconsin-Madison. 368 Pp.

SELECTED TIMBER TYPES

Jack Pine

- Jack pine forest type acreage declined by 148,000 acres between 1983 and 1996.
- Jack pine volume in trees over 5-inches in diameter decreased by 146 million cubic feet between 1983 and 1996.
- The jack pine budworm has been a significant contributor to the decline and mortality of jack pine in Wisconsin between 1983 and 1996.

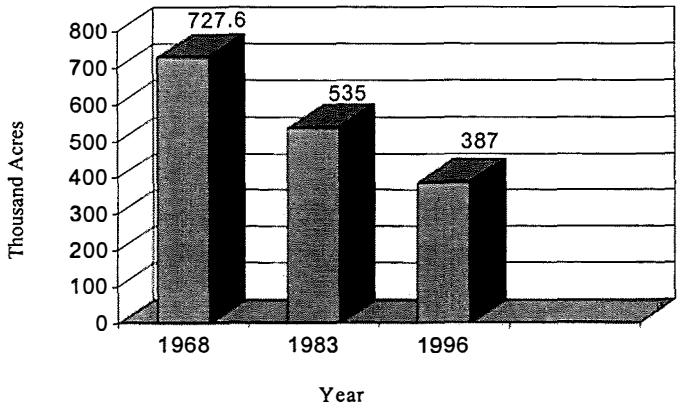


Figure 8. Jack pine forest type acreage (in thousand acres) on timberland in Wisconsin. Data taken from 1996 FIA survey.

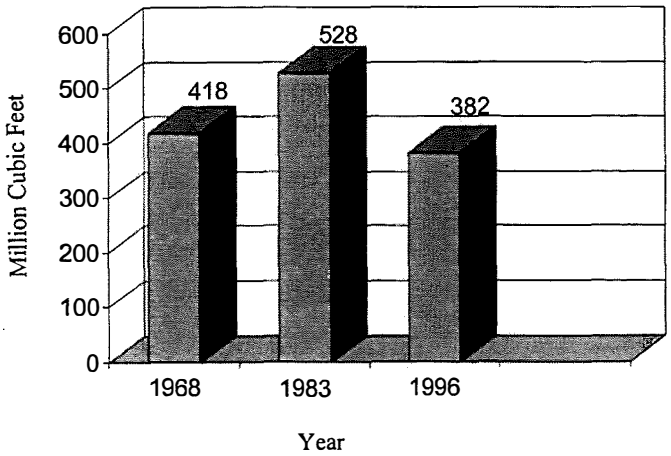


Figure 9. Growing stock volume of jack pine (in million cubic feet) on timberland in Wisconsin. Data taken from 1996 FIA survey.

Jack Pine Budworm - The History

There is no question that the most influential forest insect or disease known to affect jack pine in Wisconsin, is the jack pine budworm, *Choristoneura pinus pinus* (Freeman). This insect is native to North America and most frequently found in the Lake States and adjoining Canadian Provinces. Jack pine budworm has been documented as a defoliator of jack pine in Wisconsin since the early 1950's. The most significant outbreaks, in terms of duration and acres, have occurred in five general locations in Wisconsin (Figure 10). Since 1954, the jack pine budworm has been recorded as causing moderate to severe defoliation in Wisconsin, 31 times (Table 1).

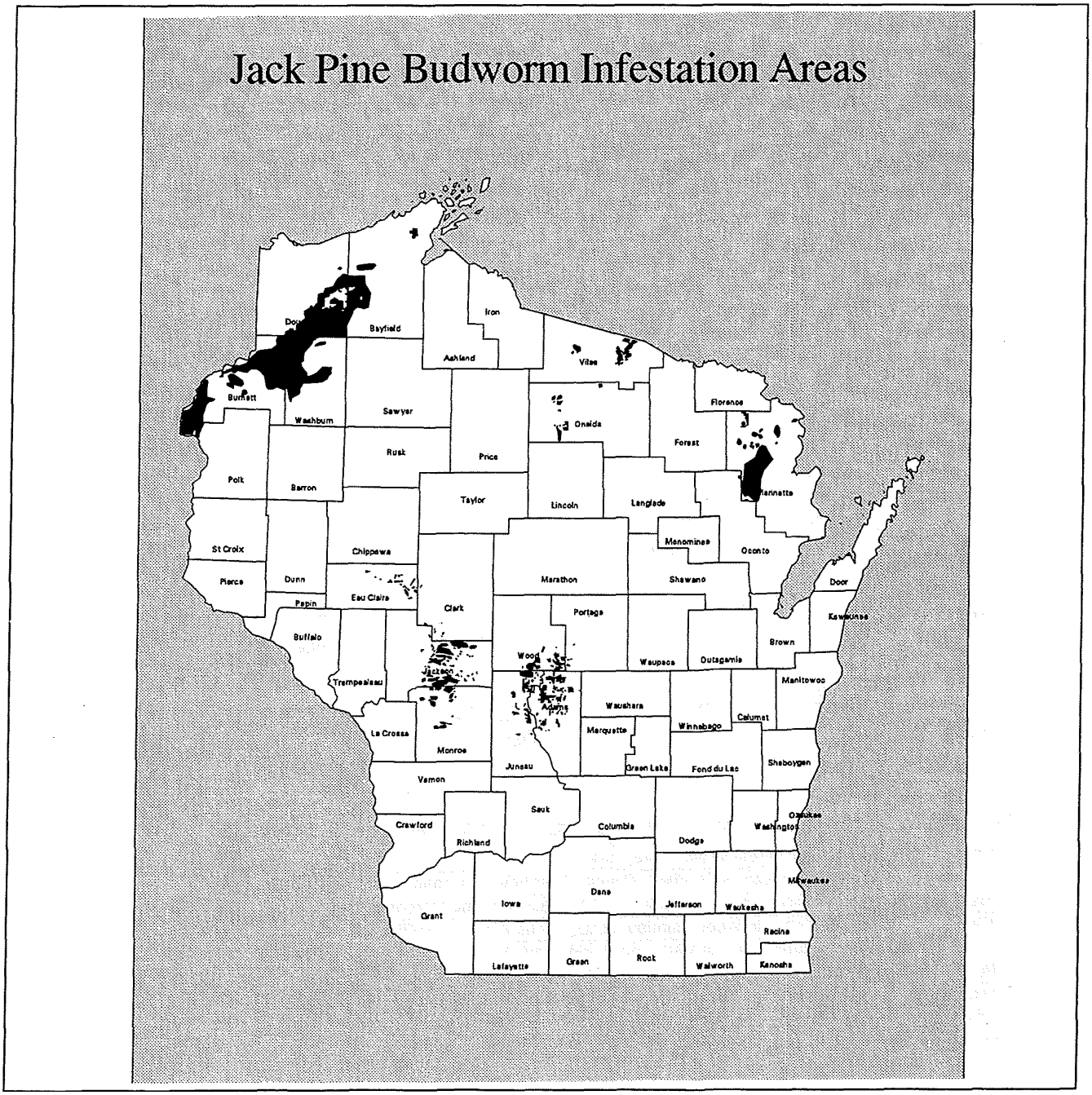


Figure 10. Locations of major jack pine budworm outbreaks, 1954-1997.

Table 1. Population trends of jack pine budworm in five geographic regions of WI[a], 1954-1996.

Year	N.W. region[b]	W.C. region[c]	Central region[d]	N.C. region[e]	N.E. region[f]
1954	Outbreak[g]				Outbreak
1955	Outbreak			Outbreak	Outbreak
1956	Outbreak				Pop. collapsed
1957	Pop. collapsed				
1958					
1959	Outbreak				
1960	Outbreak				Outbreak
1961	Outbreak				Outbreak
1962	Pop. collapsed				Pop. collapsed
1963					
1964	Outbreak				
1965	Outbreak				
1966	Outbreak			Outbreak	
1967	Outbreak			Outbreak	
1968	Pop. collapsed	Outbreak	Outbreak	Outbreak	Outbreak
1969			Outbreak	Outbreak	Outbreak
1970	Outbreak		Pop. collapsed	Pop. collapsed	Pop. collapsed
1971	Outbreak				
1972	Pop. collapsed				
1973					
1974	Outbreak				
1975	Outbreak				
1976	Pop. collapsed				
1977					
1978	Outbreak				
1979	Outbreak				
1980	Outbreak				Outbreak
1981	Outbreak				
1982	Outbreak				
1983	Outbreak	Outbreak			
1984	Outbreak	Outbreak			
1985	Outbreak	Outbreak			
1986	Pop. collapsed				
1987					
1988				Outbreak	
1989				Pop. collapsed	
1990					
1991	Outbreak				
1992	Outbreak	Outbreak	Outbreak	Outbreak	Outbreak
1993	Outbreak	Outbreak	Outbreak		Outbreak
1994	Outbreak			Outbreak	
1995	Outbreak			Outbreak	Outbreak
1996				Outbreak	

[a] Compiled from "Forest Pest Conditions in Wisconsin Annual Reports", "Forest Pest Situation Reports", and NHAL state forest larval survey data

[b] North west region includes sites in Bayfield, Douglas Washburn, Burnett, and Polk counties

[c] West central region includes sites in Eau Claire, Clark, Jackson, and Monroe counties

[d] Central region includes sites in Wood, Juneau, Portage, and Adams counties

[e] North central region includes sites in Vilas and Oneida counties

[f] North east region includes sites in Marinette, Oconto, Florence, and Menominee counties

[g] Terminology using moderate to heavy defoliation or infestation, a listing of acres defoliated or infested, or larval survey data with moderate to high larval or infestation counts were used as the basis for an outbreak.

The level of injury to jack pine depends on the severity of defoliation and the tree's vigor or ability to withstand defoliation. Repeated moderate to severe defoliation of the same stand of trees during an outbreak increases the risk of die-back and tree mortality, especially to low vigor trees. Severe defoliation can almost completely eliminate wood production by the tree during the year of defoliation. Yields in northwest Wisconsin were reduced to 33% of predicted volume during a 1970's outbreak. Defoliation also increases susceptibility of jack pine to attack from pathogens such as Armillaria root rot and secondary insects including the pine bark beetle *Ips pini*. If other stress-inducing agents, such as foliage feeding by jack pine sawfly larvae or drought, occur at the same time as budworm feeding, a greater amount of injury to jack pine can be expected.

The single most important factor playing a role in development of jack pine budworm populations is the abundance of pollen cones. Other factors such as tree age, site quality, weather and natural enemies also play a role. Management strategies that reduce the risk of significant mortality have been developed based on information on jack pine budworm population levels, host, and site factors.

Jack Pine Budworm - Current Status - 1997

Light to moderate defoliation was observed over 120,000 acres in 4 counties (Figures 11-14). Scattered small pockets (less than 10,000 acres total) of heavy defoliation occurred in Douglas, Bayfield, and Burnett counties. Surveys indicate that the population is falling in Bayfield and the northern Douglas County townships, while budworm numbers appear to be rising in Wascott Township (Douglas County) and in Washburn and Burnett counties (Appendix A).

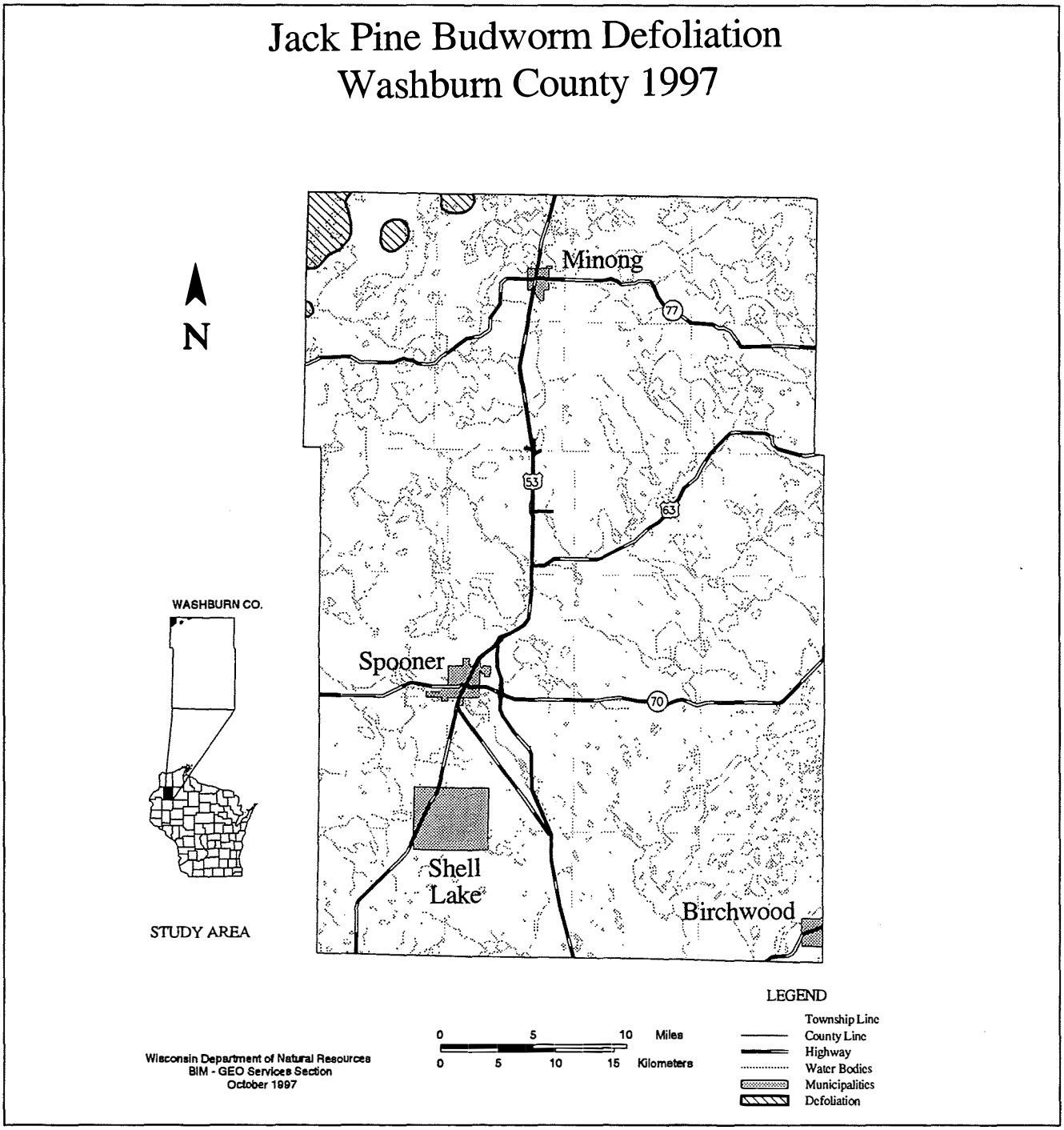


Figure 11. Area of defoliation of jack pine caused by the jack pine budworm - 1997, Washburn County.

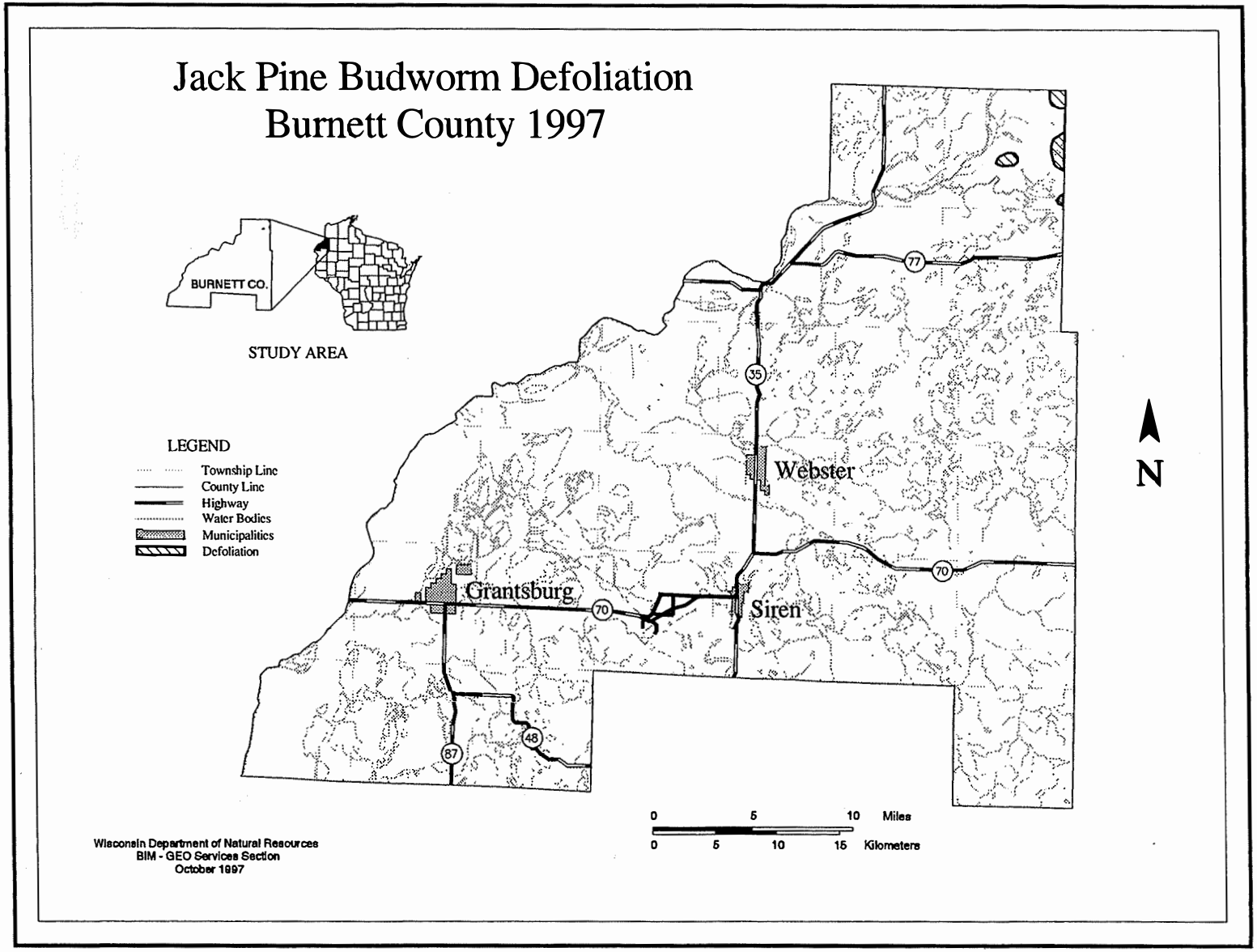


Figure 12. Area of defoliation of jack pine caused by the jack pine budworm - 1997, Burnett County.

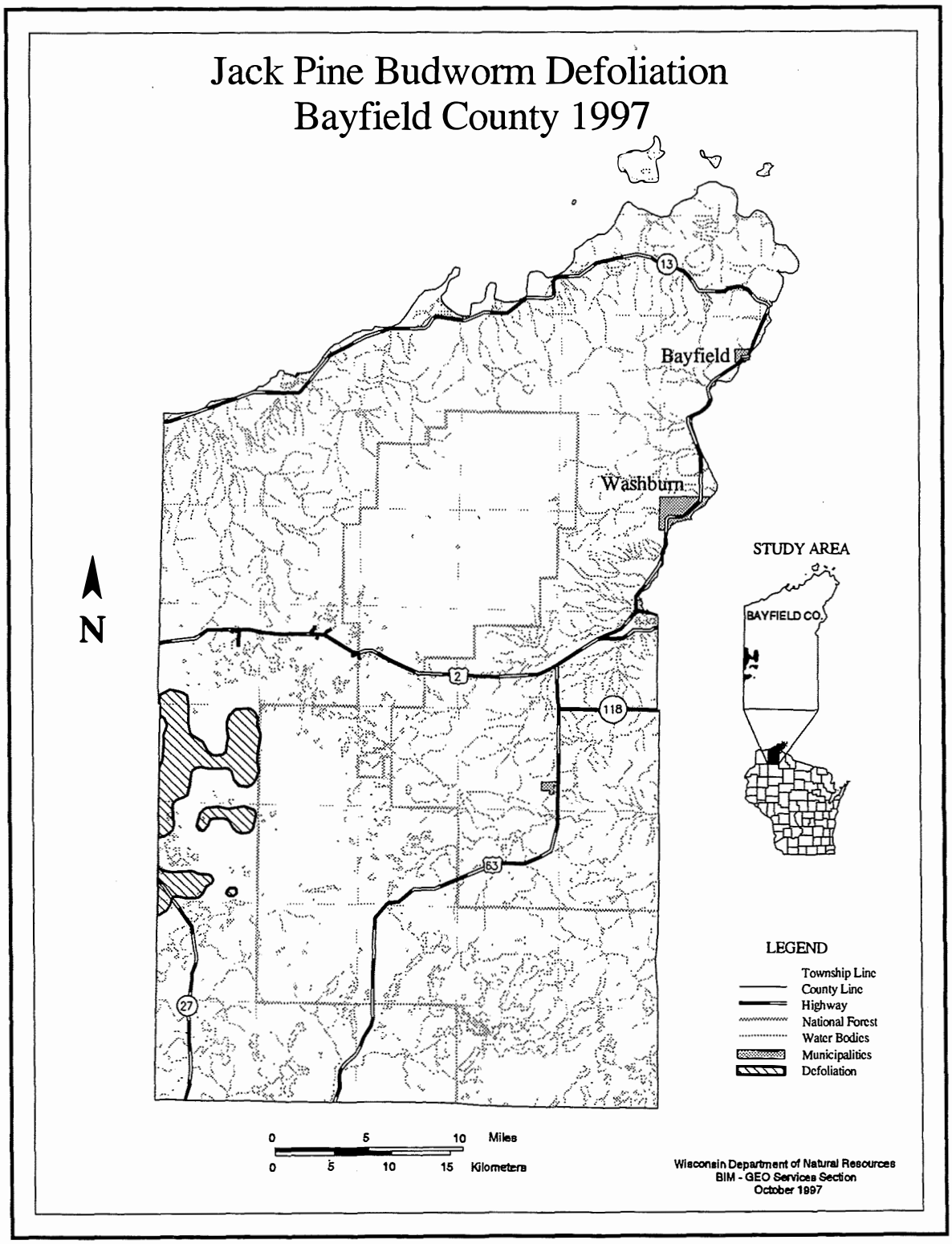


Figure 13. Area of defoliation of jack pine caused by the jack pine budworm - 1997, Bayfield County.

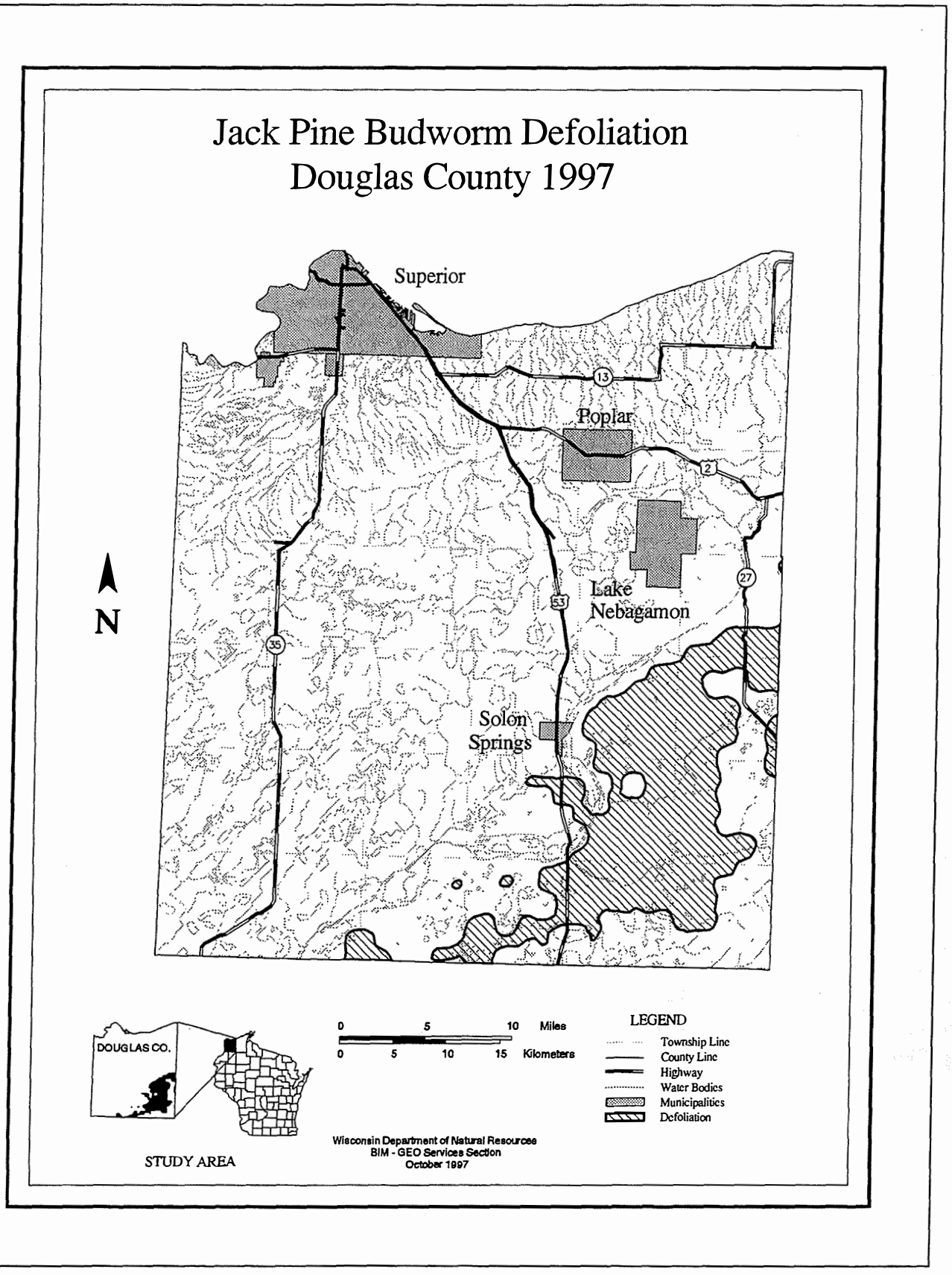


Figure 14. Area of defoliation of jack pine caused by the jack pine budworm - 1997, Douglas County.

Jack Pine Budworm - the Future as seen by Shane Weber – DNR Forest Entomologist, Spooner, WI

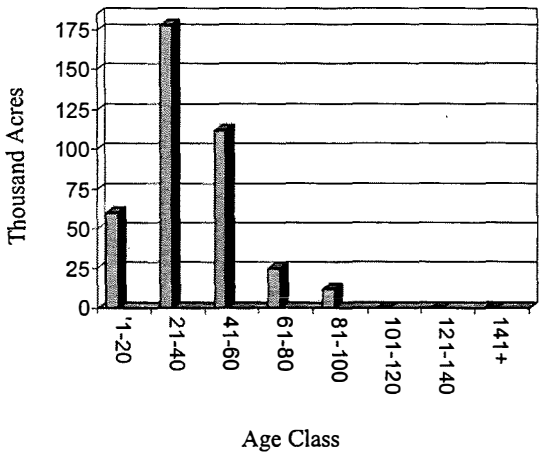


Figure 15. Age class distribution of jack pine on timberland in Wisconsin. Data taken from 1996 FIA survey.

"In the next quarter century, I expect continued jack pine budworm outbreaks in our jack pine forests of North Western Wisconsin. They should maintain their 10-12 year intervals between outbreak cycles. The outbreaks themselves should become smaller, shorter (2-3 years instead of 3-5), and less severe than our last outbreak. I believe this will be the case because the majority of our mature jack pine which sustained the 1990's outbreak have already been cut. Even as I write this, jack pines damaged in the recent attack are being felled. At no time in the next 25 years will our forests have even half the 1990 acreage of jack pine in susceptible age classes. Even beyond a quarter century I can't comprehend any convergence of forces that would recreate the vast blocks of even-aged jack pine that are needed to foster the widespread devastating budworm outbreaks of the past. First, at least 1/3 of the jack pine acres cut in the last five years have been converted to red pine. Red pines are long lived trees which are poor hosts for budworm. Acres planted now to red pine won't support jack pine budworm until after 2100. Second, our fire control personnel are remarkably efficient at preventing large fires and our sand flats now contain a scattered but substantial human population which requires protection from large wildfires. There will, however, always be enough jack pine acreage to support modest budworm eruptions since substantial areas of our sand flats are sufficiently dry and infertile to discourage red pine culture."

Oak-Hickory

- Oak-hickory forest type increased by 33,000 acres between 1983 and 1996.
- Select red oak volume in trees over 5-inches in diameter increased by 226 million cubic feet between 1983 and 1996.
- White oak volume in trees over 5-inch diameter increased by 168 million cubic feet between 1983 and 1996.
- Black, pin, and northern pin oak volume in trees over 5-inch diameter decreased slightly by 2 million cubic feet between 1983 and 1996.
- The severe drought of 1988 and '89 followed by infestations of the two-lined chestnut borer and Armillaria root rot have been significant contributors to the decline and mortality of northern pin oak and black oak in Wisconsin between 1983 and 1996.

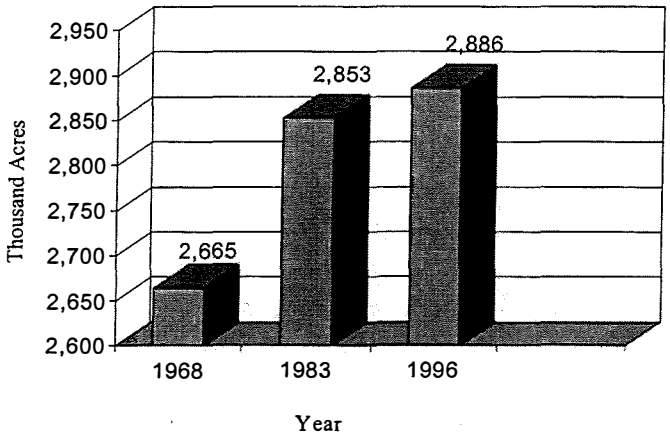


Figure 16. Oak-hickory forest type acreage (in thousand acres) on timberland in Wisconsin. Data taken from 1996 FIA survey.

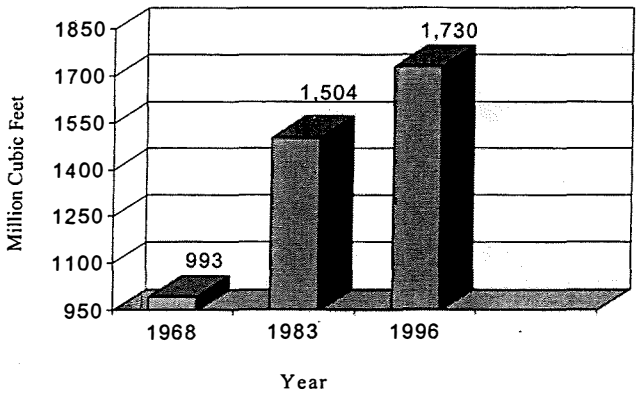


Figure 17. Growing stock volume of select red oak (in million cubic feet) on timberland in Wisconsin. Data taken from 1996 FIA survey.

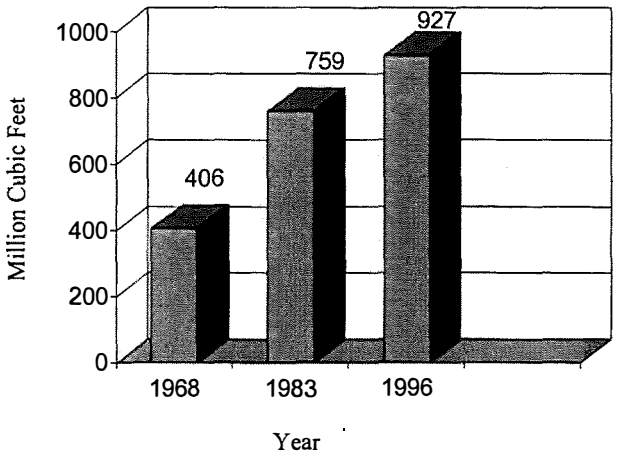


Figure 18. Growing stock volume of select white oak (in million cubic feet) on timberland in Wisconsin. Data taken from 1996 FIA survey.

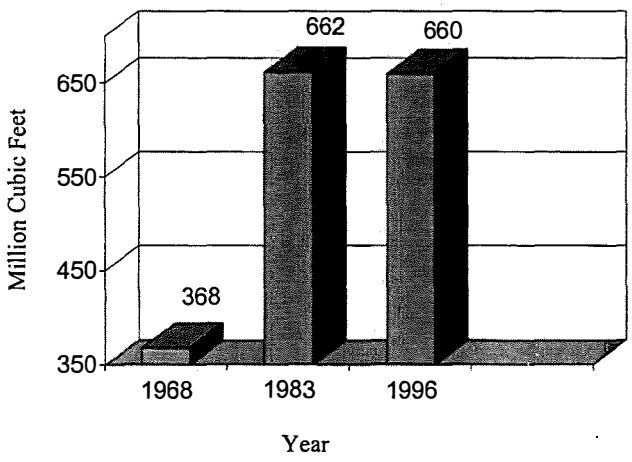


Figure 19. Growing stock volume of other red oak (in million cubic feet) on timberland in Wisconsin. Data taken from 1996 FIA survey.

Oak Decline and Mortality - The History

Oak mortality in Wisconsin has occurred in episodes following drought and insect defoliation. In the north, mortality has followed forest tent caterpillar outbreaks that occurred in the late 1970's and early 1980's and again in the late 1980's and early 1990's. Massive mortality of northern pin oak occurred in Marinette county after tent caterpillar defoliation coincided with the drought of 1988. Oak mortality occurred in Northeastern Wisconsin following an outbreak of the oak leaf tier, *Croecia semipurpurna*, in the mid 1970's.

In the central counties, the major mortality factor has been oak wilt. In general, it has not occurred in episodes; however, some years show definite increases and decreases. Increases in oak wilt incidence have also followed severe growing season wind storms.

In southern Wisconsin, major oak mortality episode followed fall cankerworm outbreaks which occurred in the late 1970's and late 1980's. The droughts of 1976 and 1988 occurred during cankerworm outbreaks. Oak mortality in each case increased greatly in the year of the drought and the year after and then declined over a period of years. In the 1970's and 80's the bulk of the mortality was in black oak. Now that black oak is becoming scarce, white oak mortality is on the rise.

Oak - Current Health Status - 1997

A large portion of Wisconsin's current oak acreage originated in the early 1900's on lands that had burned over after logging. Much of this acreage is now more than 90 years old. Our current inventory of oak exists in varied situations.

Red oak occurs in oak type, as a component of the northern hardwood, oak-hickory, and central hardwood types. Because of its relatively long life span, much of our red oak inventory is in good health – it is not over-mature.

Black oak occurs in the oak and central hardwood types and as a component of the oak-hickory type in central and southern Wisconsin. Much of the black oak is over-mature and in declining health.

Northern Pin Oak occurs in the oak, oak-hickory and central hardwood types. Much of it occurs on the poor, sandy soils of the west-central and central counties and is over-mature and in declining health.

White oak occupies a wide variety of sites in the oak-hickory, scrub oak and central hardwood types. It is a relatively long-lived tree. Where it occurs on higher quality sites, it is in generally good health; on drier sites it is showing signs of decline.

Major Pests of Oak - 1997

Gypsy Moth - *Lymantria dispar* (L.)

The Wisconsin Cooperative Gypsy Moth Program is described in The Wisconsin Gypsy Moth Strategic Plan. An associated Implementation Plan sets annual objectives for the program. Both plans are available from Wisconsin Department of Agriculture, Trade and Consumer Protection, 2811 Agriculture Drive, Madison, WI.

In 1997, twenty-four sites in 13 counties totaling 36,895 acres were sprayed with two aerial applications of *Bacillus thuringiensis var. kurstaki* at a rate of 36 BIU(96 oz) per acre (Figure 20). The spraying reduced the gypsy moth numbers in the spray blocks to below detectable levels. A small hot spot in Kenosha County was discovered in mid summer and sprayed with carbaryl from the ground.

Wisconsin's first visible gypsy moth defoliation occurred in Oconto county where a two-acre area of willow and aspen was stripped and surrounding willows were lightly defoliated. Larvae were massed on the trunks of some of the larger willows. Symptoms of the gypsy moth virus disease were present.

The entire state was trapped; over 54,000 traps were placed in densities of 1 per 4 square miles to 16 per square mile. Adult males were trapped in every county; a total of 91,905 were caught by the Department of Agriculture, Trade, and Consumer Protection (Figure 21). In addition, approximately 5,000 more moths were trapped by municipal and private cooperators. Heaviest trap catches were in the eastern counties where 20 moths per trap were common. In the western counties trap catch was well below 1 per trap.

See Appendix B for the report of the 1997 gypsy moth biological control program.

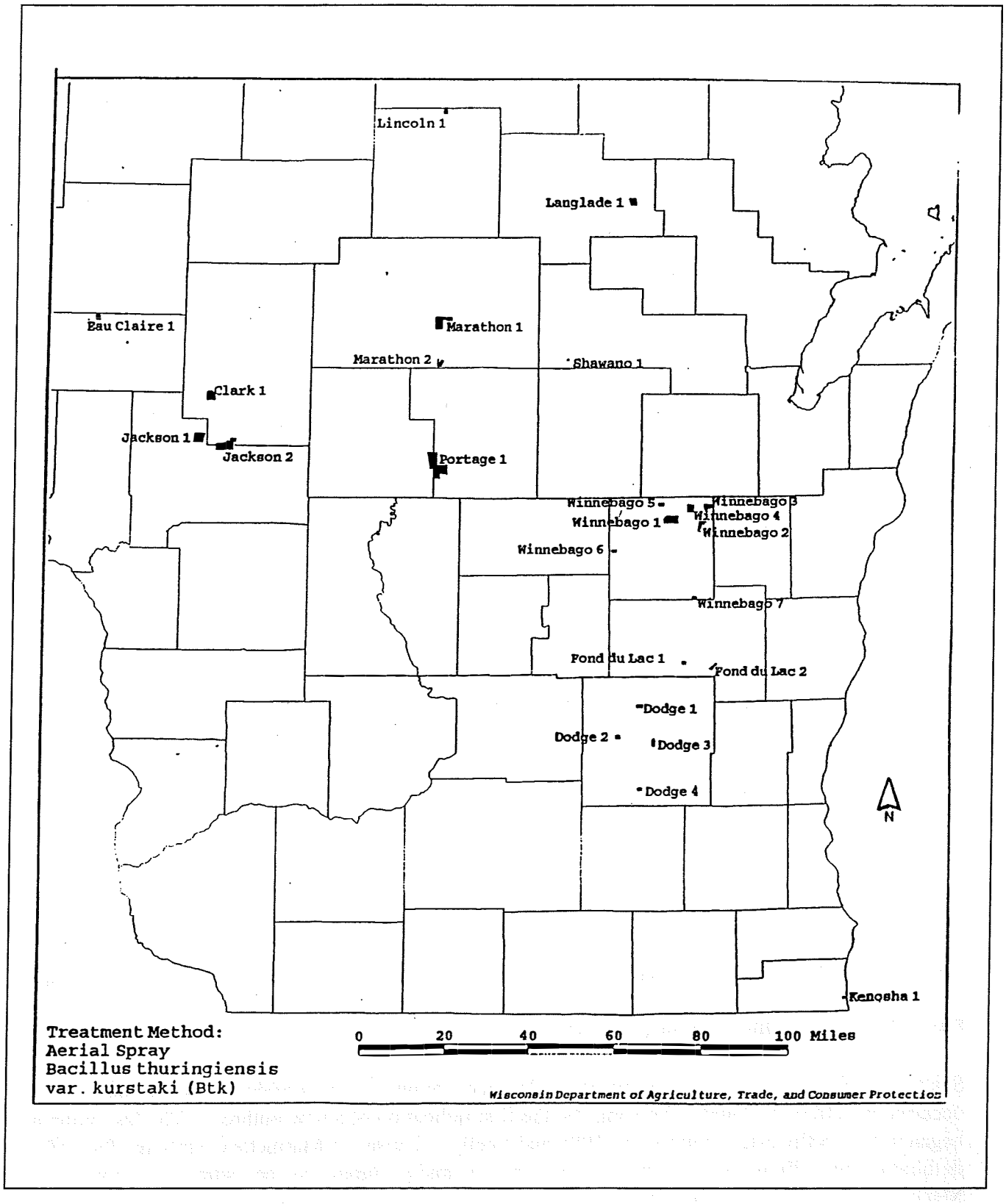


Figure 20. Gypsy moth spray blocks in Wisconsin, 1997.

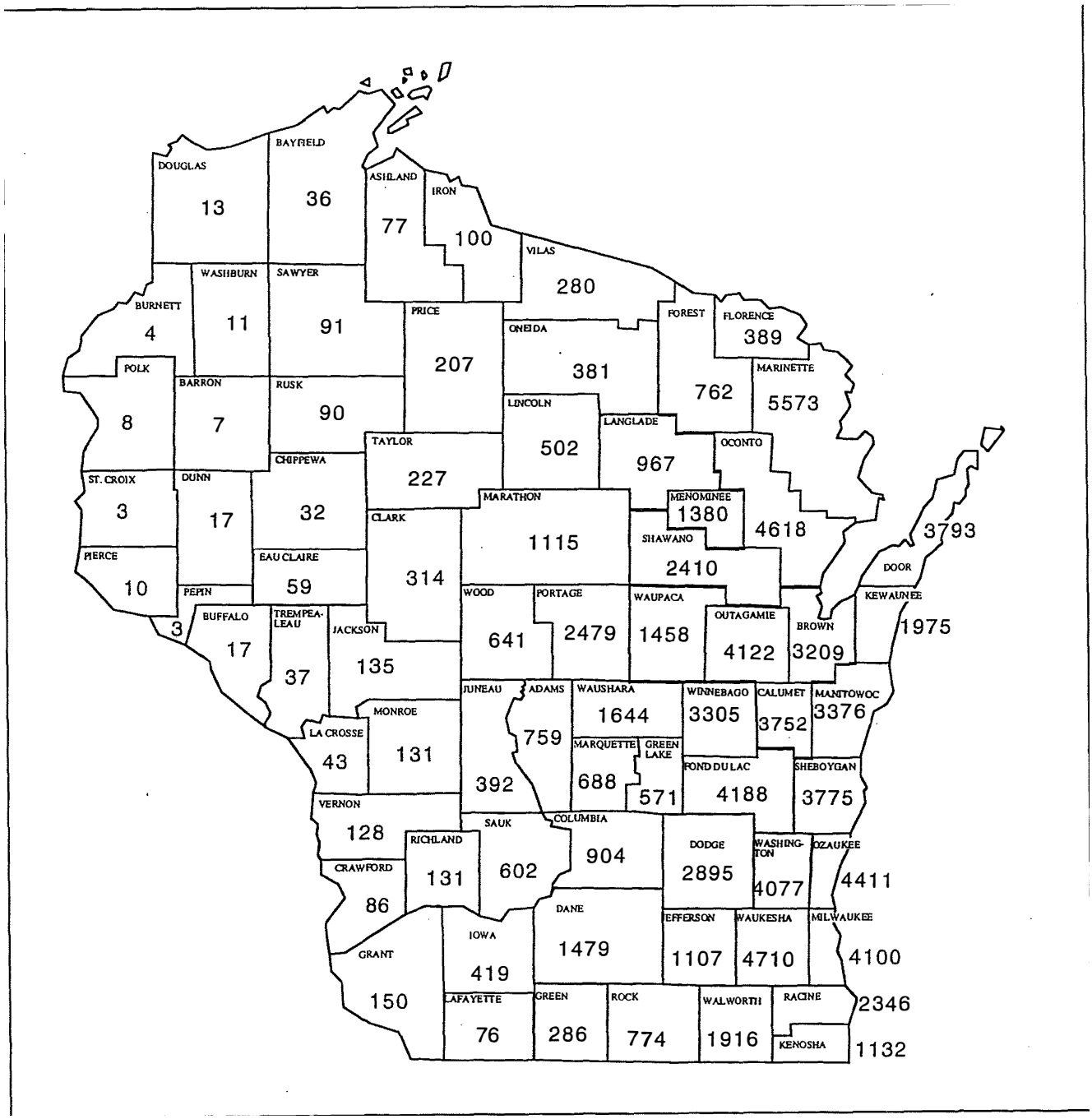


Figure 21. Number of male gypsy moths trapped by DATCP in Wisconsin during the 1997 trapping season.

Forest Tent Caterpillar - *Malacosoma disstria* Hubner

Scattered defoliation of red oak occurred in Florence County. Heavy defoliation of bur oak occurred in Jefferson County. This may be the first indication of a new outbreak. The last outbreak began in the northwestern counties in 1986 and finally collapsed in Marinette County in 1992, after defoliating many thousands of acres of aspen and oak and prompting several spray operations in Menominee and Marinette counties.

Oak Wilt - *Ceratocystis fagacearum* (Bretz) Hunt

This disease continues to move, primarily through root-graft spread, throughout the southern 2/3 of the state. Public interest in oak wilt has increased dramatically due primarily to a campaign by the Wisconsin Garden Club Federation and homes being contrusted in oak woodlands.. Communities in the southern 2/3 of the state, where development is stretching out into the oak woodlands are at the greatest risk for initiating new pockets of disease. A committee - chaired by Dr. Bob Miller, UW-Stevens Point - is addressing management of oak wilt in communities and has developed a draft model oak wilt ordinance. A copy of the ordinance can be ordered in the New Publications section.

Survey efforts continue to be focused on determining the effectiveness of pruning and cutting guidelines developed for Wisconsin's electric utilities; 1997 was the third year of this survey. Results indicate - in the areas surveyed - overland spread of oak wilt is not occurring via pruning of oak by Wisconsin Power & Light (WP&L) in southwestern south central Wisconsin. This company does prune in selected rural areas during the susceptible time, (April 15 - July 1) but uses a tree wound dressing immediately after pruning. This survey will continue for 2 more years.

In southern WI, few new pockets were observed and mortality in existing pockets was very low. However, three new pockets appeared in northwest Wisconsin in Burnett County. Spread of the fungus in existing pockets was considerable there. In western Wisconsin, symptoms were observed on red and white oak. There was slow spread northward at the leading edge in Marinette County. The greatest concentration in this county still appears to be near Crivitz.

The Future for Oak

Gypsy Moth constitutes the greatest threat to oak management in Wisconsin. Outbreaks will be more frequent and severe in the central and southwestern counties where white, black and northern pin oaks occur on dry, sandy plains and on south and west facing slopes of the driftless area. The poor health of much of this oak will contribute to significant mortality during the next 10 years. In the northern and eastern counties, red oak is more common. It tends to occur on the higher quality habitat types and in mixtures that do not favor gypsy moth build up. Outbreaks will be less severe and frequent here.

Heavy defoliation of oak also drastically reduces the acorn crop which many wildlife species depend on.

Following defoliation and subsequent oak mortality, the proportion of oak in mixed stands will decrease leaving higher proportions of tree species that the gypsy moth does not readily feed on. Over time, the forest will become more resistant to gypsy moth which will reduce frequency and severity of outbreaks.

The **Forest Tent Caterpillar** will periodically cause heavy spring defoliation to oaks in northern Wisconsin as it has in the past. Scattered mortality will follow defoliation in most sites. Heavy mortality will follow defoliation in stands that are overcrowded and stands that occupy the poorest habitat types.

Oak Wilt will continue to spread through root grafts and kill pockets of oak, especially in the central counties where pine and other non-oak species often regenerate. Over time, the wide expanses of oak in the central and western counties will convert to a diverse patchwork of oak, pine and other hardwoods. Movement of oak wilt into northern counties is expected to be slow, especially in areas where oak is a minor component of the forest stand.

Public awareness is expected to continue its sky-rocketing increase as people move into wooded areas as this disease becomes more prevalent in urban areas. Requests for information and assistance in developing oak wilt management plans for communities and woodland owners is expected to increase. Demands for alternative strategies for managing oak wilt in woodlands is already high and expected to continue, thus pest specialists will be working closely with research partners in Missouri to determine the potential use of herbicides in creating a barrier to root-graft spread.

Paper Birch

- Paper birch forest type acreage declined by 265,000 acres between 1983 and 1996.
- Paper birch volume in trees over 5-inch diameter decreased by 258 million cubic feet between 1983 and 1996.
- The severe drought of 1988 and '89, in combination with defoliation caused by the birch leaf miner and infestations of the bronze birch borer contributed significantly to the decline and mortality of paper birch between 1983 and 1996.

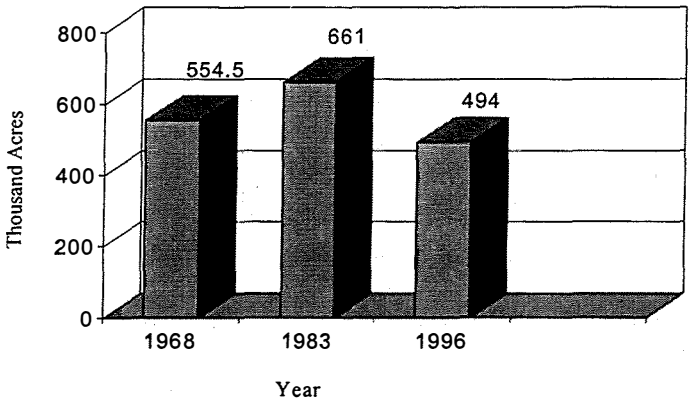


Figure 22. Paper birch forest type acreage (in thousand acres) on timberland in Wisconsin. Data taken from 1996 FIA survey.

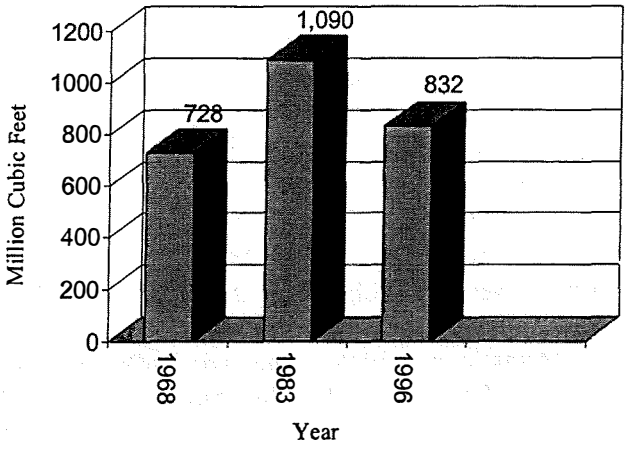


Figure 23. Growing stock volume of paper birch (in million cubic feet) on timberland in Wisconsin. Data taken from 1996 FIA survey.

Paper Birch - The History

In 1988 and 1989, a combination of factors caused widespread dieback and mortality of white birch in northern Wisconsin, the Upper Peninsula of Michigan and northern Minnesota. Leaf-feeding by the birch leaf miner (*Fenusa pusilla* [Lepel etieb]), a severe two-year drought, and cambium-feeding by the bronze birch borer were the three factors that had a major impact of the health of white birch.

White birch is a relatively short-lived species with an average life expectancy of 70-110 years. In the late 1980's the white birch resource was predominantly in the older age classes. As white birch ages, multiple insect and disease agents, including stem decay, can stress this species and make it more vulnerable to injury from factors such as drought.

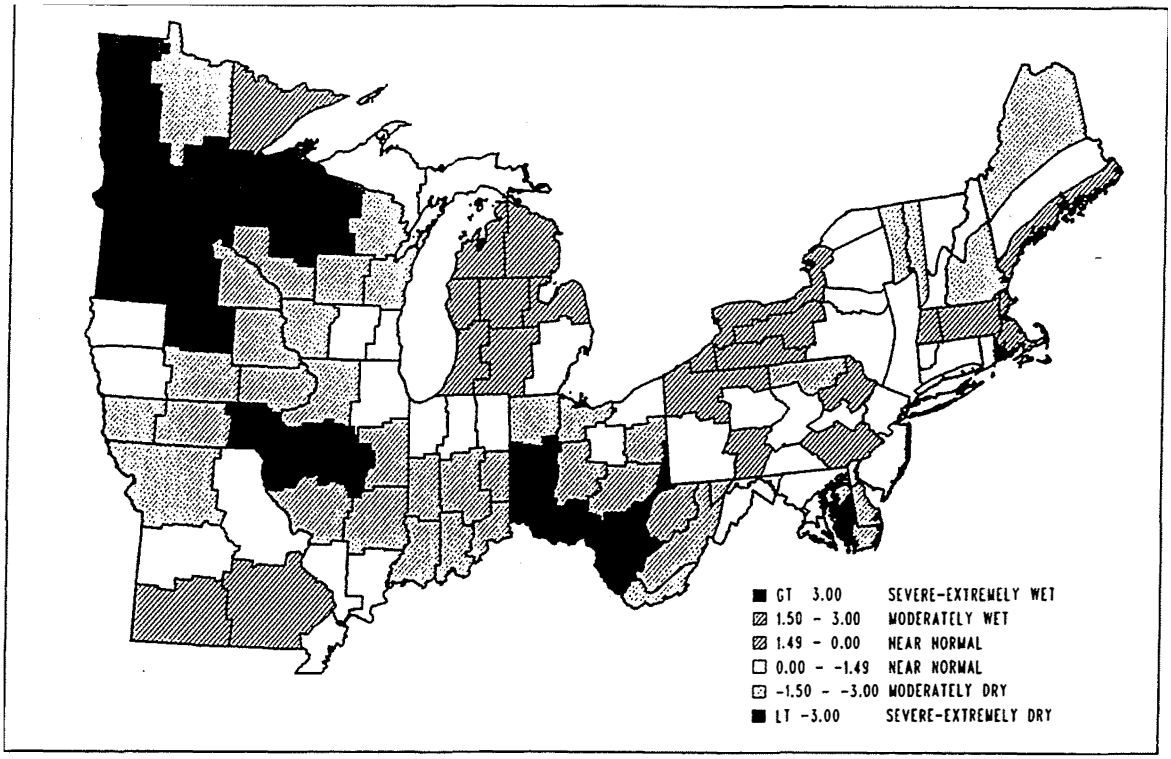
In 1988, '89 and '90, widespread defoliation by the leaf minor was reported throughout northern Wisconsin in June. In many cases, the feeding damage occurred on more than 50% of an individual tree's crown. When this happened, affected trees refoliated, depleting starch reserves in the tree's roots. Significant stress was placed on the white birch as this process was repeated for three years. Eventually, dieback in the upper and outer crown was observed, followed by decline and mortality.

In addition to feeding by the leaf minor, a severe drought occurred in 1988 and 1989 throughout the Lake States (Figure 24). Healthy, vigorous white birch may resist borer infestations and borer larvae may not be able to survive in healthy trees. But white birch stressed by defoliation and drought becomes highly vulnerable to attack by the borer.

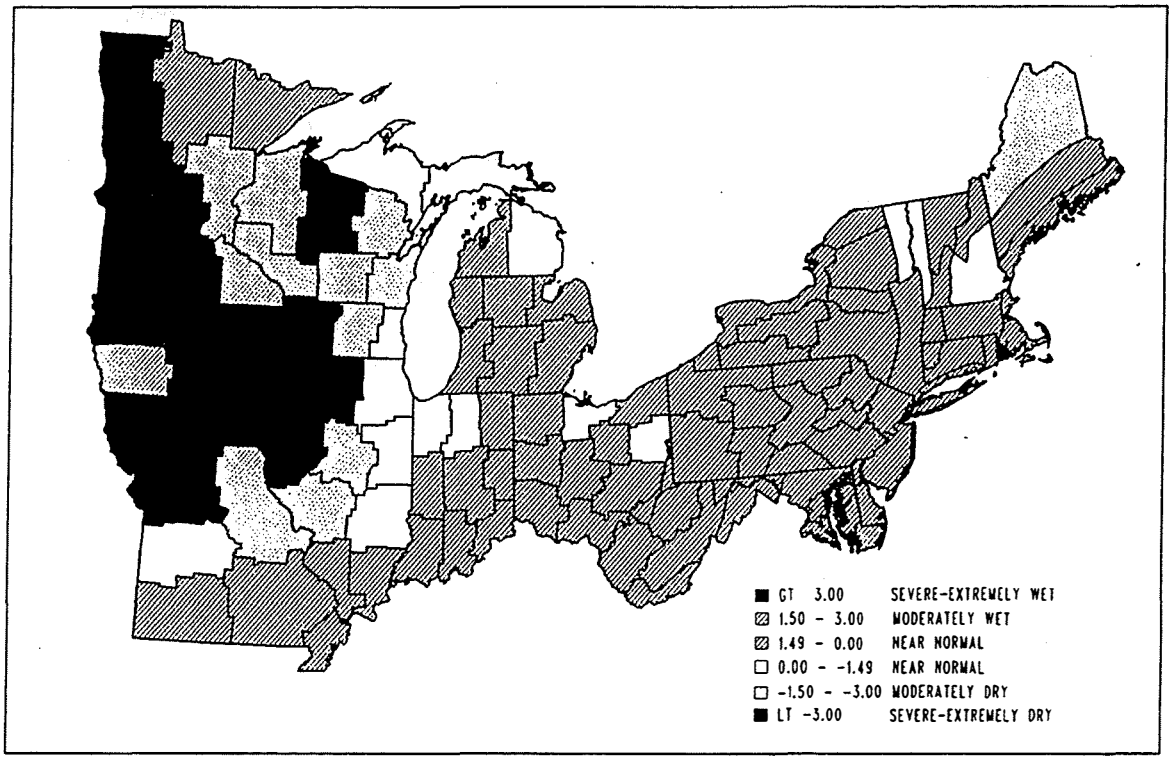
Surveys to determine the impact of this complex on the birch resource were conducted in the early 1990's in northern Minnesota, the Upper Peninsula of Michigan and north-central Wisconsin. In Minnesota, 1,355 white birch were evaluated in 5 counties. Of the 1,355 white birch evaluated, 20% or 271 trees died between 1990 and 1992. The statewide estimate of mortality of white birch for Minnesota during the 1990 to 1992 period was 105,440,000 trees. This data indicates a 400% increase in the annual birch mortality in the late 1980's and early 1990's compared to the birch mortality experienced from the mid-1970's to the late 1980's. Mortality and decline did not correlate with tree age.

In Michigan, seventeen birch stands were surveyed in 1993 in the central and western Upper Peninsula. Three hundred six plots were sampled on 766 acres. The average stand age was 68. Dead trees combined with trees with greater than 60% of their upper crowns dead, totaled 15.8% of the total white birch volume . Mortality and decline did not correlate with tree age; trees of all size classes were equally effected.

In Wisconsin, efforts were concentrated on surveying the white birch on the Oneida County Forest in 1990 - 92, by DNR and County foresters. Nine stands were surveyed and observations were made on 785, 786 and 776 trees in 1990, '91, and '92 respectively. Data were collected on trees located in 10-basal area factor plots located along a predetermined cruise course. Mortality and dieback data were collected as well as habitat type. Healthy white birch constituted 73, 88 and 79 percent of the white birch observed in 1990, '91 and '92 respectively. Dead white birch constituted 4, 5 and 15% of the white birch observed in 1990, '91, and '92 respectively.


GT 3.00 SEVERE-EXTREMELY WET
1.50 - 3.00 MODERATELY WET
1.49 - 0.00 NEAR NORMAL
0.00 - -1.49 NEAR NORMAL
-1.50 - -3.00 MODERATELY DRY
LT -3.00 SEVERE-EXTREMELY DRY

Palmer Hydrologic Drought Index, 1988 by Climate Division (Produced by: USDA Forest Service, Northeastern Area - Forest Health Monitoring GIS Group).


GT 3.00 SEVERE-EXTREMELY WET
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-1.50 - -3.00 MODERATELY DRY
LT -3.00 SEVERE-EXTREMELY DRY

Palmer Hydrologic Drought Index, 1989 by Climate Division (Produced by: USDA Forest Service, Northeastern Area - Forest Health Monitoring GIS Group).

Figure 24. Palmer drought index illustrating drought of 1988 and 1989.

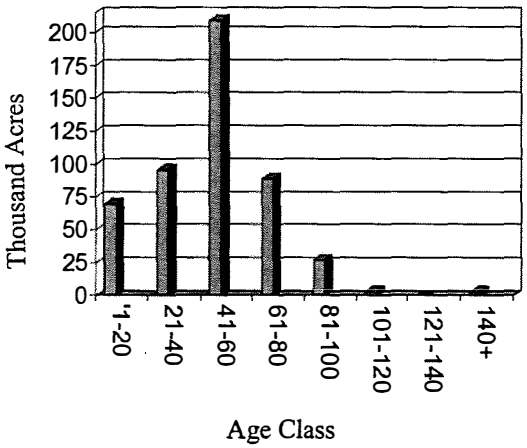

Figure 25. Age class distribution of paper brich (in thousand acres) on timberland in Wisconsin. Data taken from 1996 FIA survey.

In Wisconsin, where mortality occurred, regeneration of paper birch was variable and often nonexistent. Feeding on regeneration, by the white-tailed deer was one of the major factors that limited successful regeneration.

No widespread defoliation of paper birch was observed in 1997. The age-class distribution of paper birch indicates the highest number of acres is in the 41-60 age group. The trees in this age class and those in younger classes will be less likely to decline if an outbreak of Birch Leaf Miner or a one-year drought occurs. Birch in the older age classes will be more susceptible to decline following a one-year drought or defoliation. If another two-three year drought occurs in combination with defoliation, birch in all age classes are expected to decline and die.

Maple-Basswood

- Maple-basswood forest type acreage increased by 1.2 million acres between 1982 and 1996.
- Hard maple volume in trees over 5-inch diameter increased by 540 million cubic feet between 1983 and 1996.
- Soft maple volume in trees over 5-inch diameter increased by 685 million cubic feet between 1983 and 1996.
- The most common disturbance agents in the maple-basswood forest are defoliators such as the forest tent caterpillar and basswood thrips, root rot caused by Armillaria spp., severe drought and severe cold.
- Ten years of monitoring the health of sugar maple in a permanent plot network, indicate the health of sugar maple, in general is very good .
- The quality of sugar maple trees is of interest and concern to some wood-utilizing industries. Decay and discoloration of sugar maple is widespread throughout Wisconsin and due primarily to wounding.

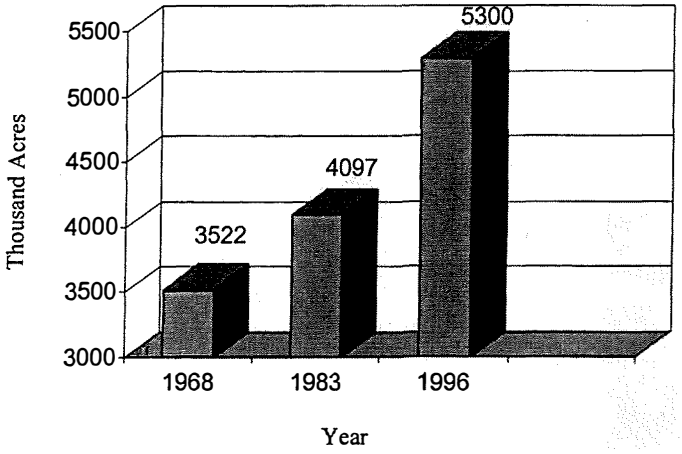

Figure 26. Maple-basswood forest type acreage (in thousand acres) on timberland in Wisconsin. Data taken from 1996 FIA survey.

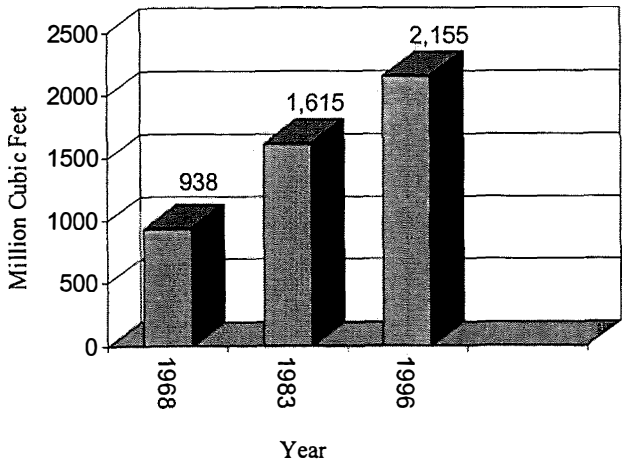

Figure 27. Growing stock volume of hard maple (in million cubic feet) on timberland in Wisconsin. Data taken from 1996 FIA survey.

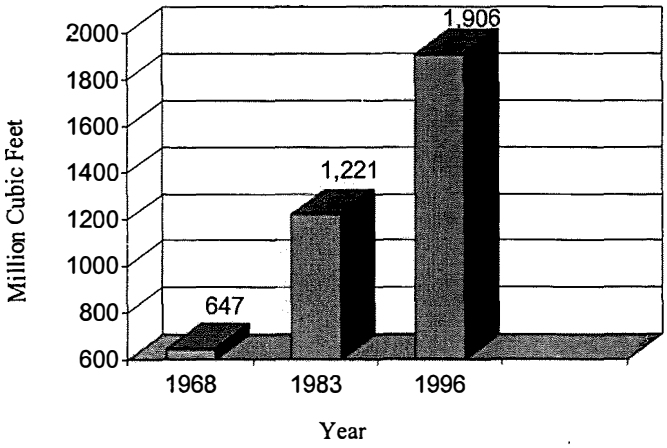

Figure 28. Growing stock volume of soft maple (in million cubic feet) on timberland in Wisconsin. Data taken from 1996 FIA survey.

Maple-Basswood - The History

Observations of defoliation of sugar maple and basswood by various pests has been recorded since the late 1950's. The most common defoliators of sugar maple include:
Forest tent caterpillar, *Malacosoma disstria*, and Bruce spanworm, *Operophtera bruceata*. A less frequently observed defoliator is the Orange-humped mapleworm, *Symmerista leucitys*. The most common defoliator of basswood is the introduced basswood thrips. Endemic populations of these insects keep them ever present in our forests at low levels. Various factors, including weather conditions and predator or parasite populations can influence the population of these defoliators. Widespread defoliation of maple and basswood will often last 2-3 years, followed by a sudden decrease in the population of the defoliator. Armillaria root rot is common in Wisconsin's maple-basswood forests and plays a role in the decline and mortality of these species once they are brought under stress.

The most severe decline and mortality of sugar maple on record, occurred in Florence County in the late 1950's. Defoliation by the maple leafroller, *Sparganothis acerivorana*, the lesser maple leafroller, *Acleris chalybeana*, and the maple webworm, *Tetralopha asperatella* in combination with a drought, put sugar maple under severe stress. Armillaria root rot was also part of this complex, infected stressed trees.

Different types of sugar maple surveys in Wisconsin have reported the health of this species to be good to excellent. In 1987, Wisconsin became participant in the North American Maple Project (NAMP). This permanent plot network was designed to look at the health of sugar maple in natural stand and stands used to produce maple syrup. Eighteen plots were set in place throughout the northern maple resource (Figure 29). Data is collected annually on various crown symptoms, including dieback, defoliation and crown transparency. Data on the presence of damages including wounds, cracks and the presence of decay fungi are also recorded. During the 10 year survey the transparency of maple crowns increased significantly only once and that was one year following the 1988 drought. It is likely that the drought induced the formation of very small leaves. In the years following the 1988, '89 drought, the crowns were fuller and produced larger leaves and the transparency ratings went down, indicating the trees had recovered.

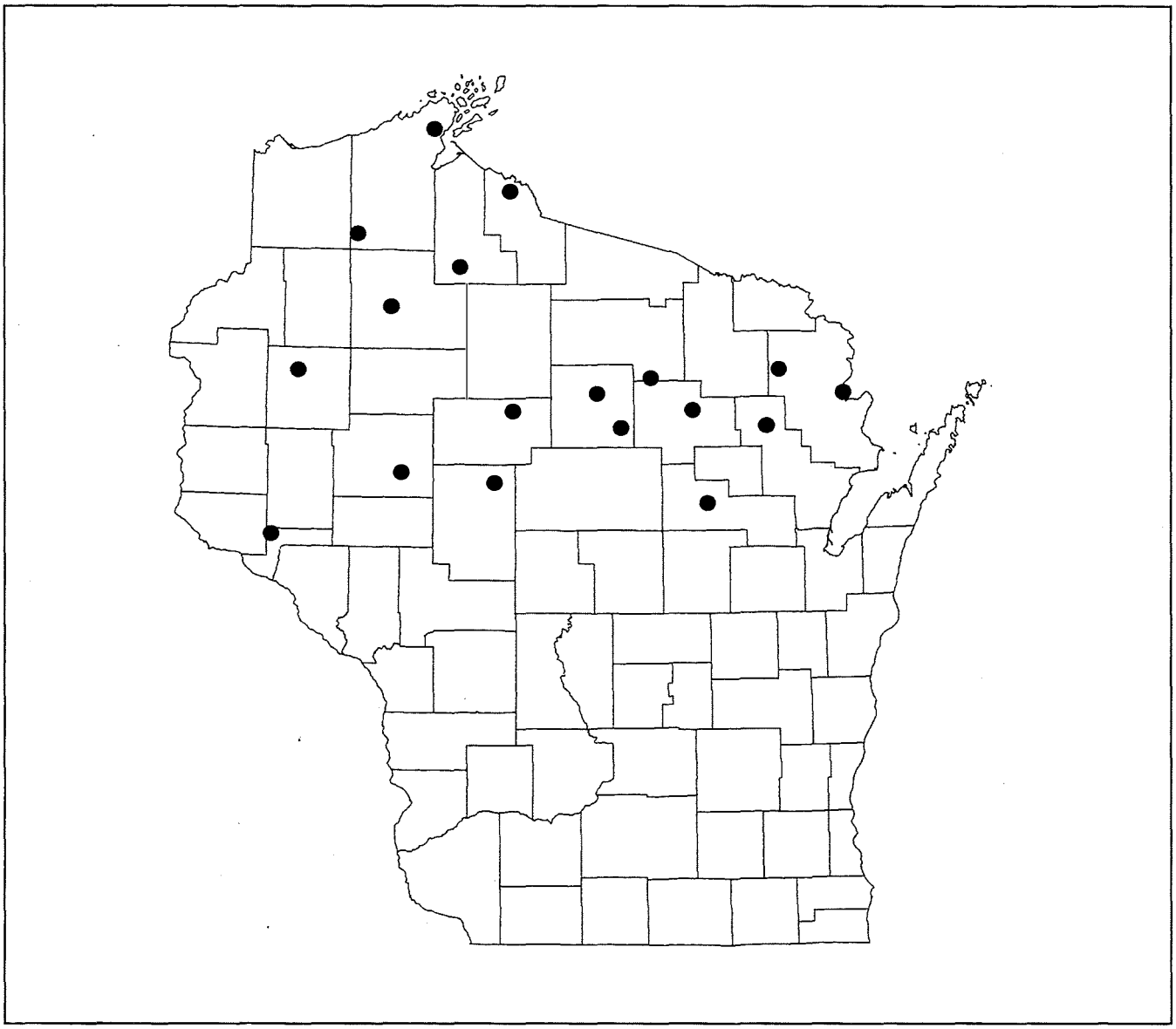

Figure 29. North American Maple Project (NAMP) Plots in Wisconsin.

Assessment of the Health of Sugar Maple and Associated Northern Hardwoods 1987-1988 (Mielke etal., 1991; see recent publications)

In 1987 and '88, a survey to determine the health of sugar maple and associated hardwoods was conducted across a west-east air quality gradient in northern Wisconsin. Counties along the gradient were grouped into four zones based on the average weighted mean pH of rainfall (Figure 30).

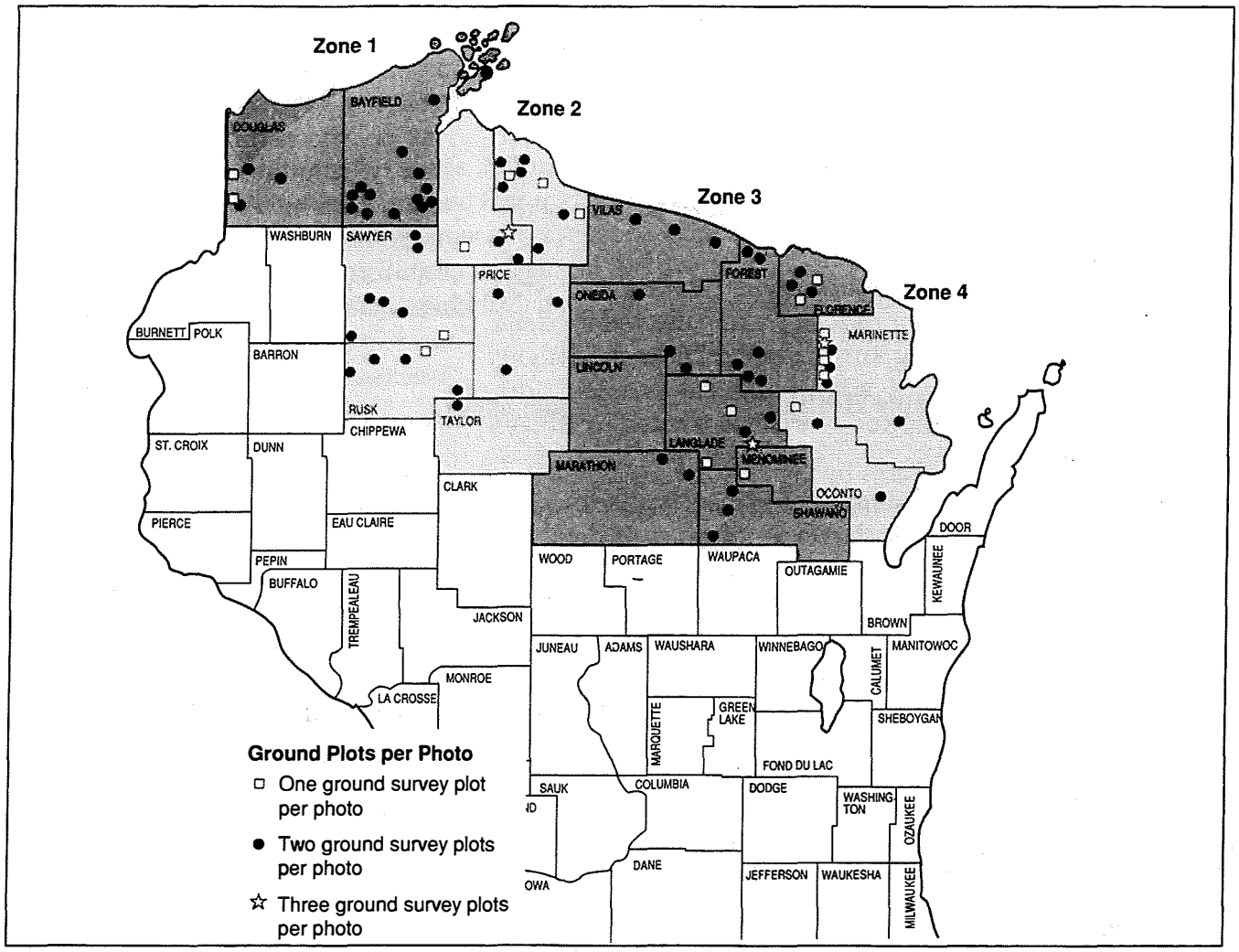

Figure 30. Plot locations and pH zones for northern hardwood health survey.

Forested areas were classified into vegetation types and health classes using color-infrared aerial photography. Zone 4 (rainfall pH less than 4.4) in northeastern Wisconsin has relatively more northern hardwood forest with lower levels of mortality and decline, than Zone 1 (rainfall pH greater than or equal to 4.8) in northwestern Wisconsin. This difference is due to the greater number of dead and declining elms in Zone 1 versus Zone 4, and not directly to the pH gradient itself..

Across all zones, there was an average of about 178 healthy trees (greater than 5 inches dbh) per acre in the northern hardwood type. About 92 trees per acre, or 52 percent, are healthy sugar maple. Approximately 2 percent of sugar maple number, basal area, and volume per acre in the northern

hardwood forest are dead or declining. The percentage of dead and declining sugar maple is more of less proportional to the number, basal area, and volume of sugar maple per acre in each diameter class. About 21 percent of the northern hardwood forest (19,236 acres) had five or more dead or declining hardwoods per acre.

There were no significant differences among zones in the estimates of number, basal area and volume of trees per acre for any of the tree health classes for sugar maple and all associated species. In general, the parameter estimates within a given zone are ordered: recent dead less than declining and old dead, and all much less than healthy. There were no statistical differences among zones in the distribution of dieback and decline of dominant and codominant sugar maple.

Of the total number of dead and declining trees surveyed (1,656), about 50 percent were elms, 10 percent were sugar maple, 9 percent were aspen, 9 percent were conifers, 5 percent were yellow birch, and 4 percent were basswood. Dutch elm disease was presumably responsible for the mortality and decline of elms. Of the dead and declining sugar maple, 32 percent were associated with Armillaria root disease, and 36 percent of the dead and declining sugar maple were not associated with any readily identifiable pest.

Investigation of Sugar Maple Health in Wisconsin Sugarbushes

In 1990, in response to concerns by the maple syrup producers, a survey of 42 sugar bushes was initiated. The health of sugar maples with a diameter of 5 inches or more was evaluated. Crown dieback, crown vigor, condition of the trunk and root collar and presence of diseases and insects were noted. A decline severity index was also given to each tree evaluated. The general condition of each sugar bush was also assessed. Approximately 95 percent of 3,140 dominant/codominant sugar maple examined had healthy crowns. Of the 42 sugarbushes examined, 13 were rated excellent (overall stand healthy), 22 were rated good (some dieback but not alarming) 6 were rated fair (obvious dieback, a potential problem), and 1 was rated poor (serious dieback and death of trees). Results from this survey indicated there was not a widespread maple dieback problem in Wisconsin's sugarbushes.

Major Pests of Maple - 1997

Greenstriped Mapleworm - *Sryocampa rubicunda*

This pest caused moderate to heavy defoliation on 5,500 acres of red maple (Figure 31). Scattered pockets infested with greenstriped mapleworm occurred from just southwest of Hayward to the outskirts of Spooner (Washburn County). The damage occurred in late July - late enough that the defoliated trees did not reflush in 1997. The impact of greenstriped mapleworm on the northern hardwood resource will be minimal because it is a specialist on red maple, and even defoliated red maples should suffer only minor growth loss due to the timing of the defoliation. The major complaint with this critter is the loss of fall color along lake shores. This insect also draws interest because of its spectacularly beautiful adults. The 30 acres of silver maple defoliation in Interstate Park (Polk County) will bear watching because these trees did partially reflush before fall.

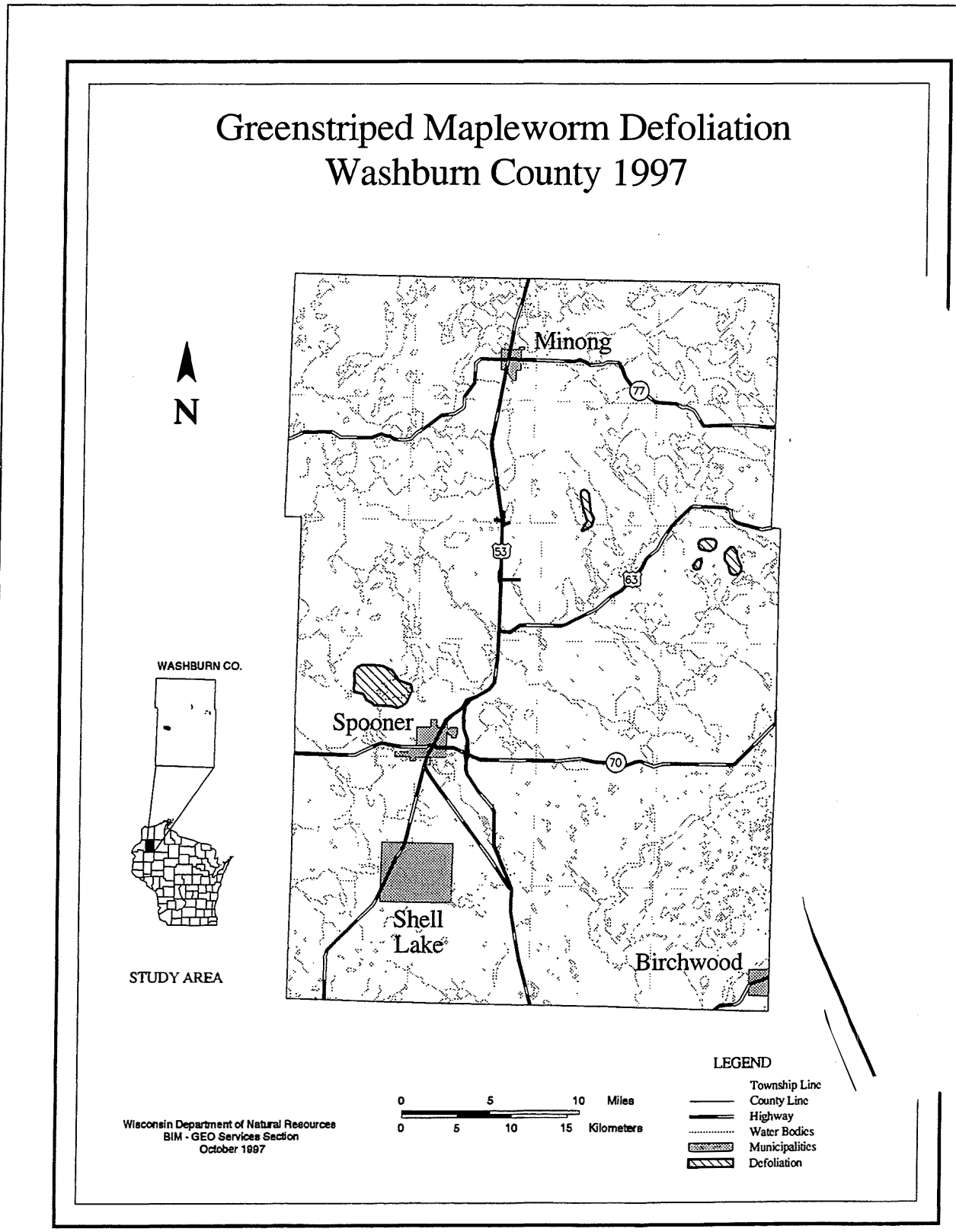

Figure 31. Area of defoliation of red maple caused by the greenstriped mapleworm, 1997 - Washburn County.

Maple-Basswood - The Future - By Shane Weber, DNR Forest Entomologist - Spooner, WI

I would expect the acreage and growing stock volume of this timber type to continue to increase in the future. This is a climax type. Many high quality red oak stands will convert to northern hardwoods despite our heroic to expensive efforts to maintain oak on these excellent sites. These tree species are not favored as hosts by gypsy moth while oak, birch, and aspen are top quality gypsy moth hosts. This selective pressure should shift more sites toward maple-basswood. With the exception of Introduced Basswood Thrips, this timber type lacks major insect to disease threats. Finally, basswood is extremely tough and resilient. Our basswood stands weathered near total UBT defoliation during the 87-89 draught without suffering widespread mortality.

Summary of Other Pests Reported in 1997

Pest	Host		Location
ASH			
Ash Plant Bug *(Tropidosteptes amoenus)*	Ash	Light to heavy feeding damage – heavy damage on already stressed trees.	Marathon County
Cold Injury	Ash	Trees were late to leaf out and had very sparse, thin crowns.	Throughout the West Central Region (WCR)
Eastern Ash Bark Beetle *(Hylesinus aculeatus)*	Ash	Branch dieback.	Marathon County
ASPEN			
Willow Sawfly *(Nematus salicisodoratus)*	Aspen	Scattered pockets of light to heavy defoliation.	Burnett, Polk, Washburn counties
BASSWOOD			
Basswood Thrips *(Thrips calcaratus)*	Basswood	Scattered pockets of light defoliation.	Rusk, Sawyer counties
Variable Oak Leaf Caterpillar *(Heterocampa manteo)*	Basswood	Light defoliation over wide areas, with <100 acre pockets of severe defoliation.	Ashland, Bayfield, Price, Sawyer counties
CHERRY			
Cherry Scallop Shell Moth *(Hydria prunivorata)*	Cherry	Webbing of leaves ranged from light to heavy, along with associated feeding.	Throughout WCR, but heavy in Adams, Jackson, Juneau, Monroe, Portage, Wood counties
Cherry Scallop Shell Moth (*Hydria prunivorata*)	Black Cherry	Heavy defoliation for second consecutive year.	Sauk County
Eastern Tent Caterpillar *(Malacosoma americanum)*	Cherry and Flowering Crabs	Small number of tents and light to moderate defoliation.	Scattered throughout the WCR
CHRISTMAS TREES			
Zimmerman Pine Moth *(Dioryctria zimmermanni)*	Scotch and White Pine	Some branch mortality and damage to main trunk.	Eau Claire, Wood counties
White Pine Weevil *(Pissodes strobi)*	Spruce	Small number of terminal leaders killed.	Chippewa County
Rhizosphaera Needlecast *(Rhizosphaera pini)*	Spruce	Light needle discoloration and needle loss.	Chippewa County
Pine Spittlebug *(Aphrophora parallela)*	Scotch Pine	High number of spittle masses on branches and tree trunks.	Wood County

Pine Pitch Midge *(Cecidomyia candidipes)*	White Pine	Very few pitch masses found during survey. Majority of pitch masses were found near the trunk.	Jackson County
White Pine Tip Weevil *(Pissodes strobi)*	Norway Spruce	Damage.	Oconto County
Red Turpentine Beetle *(Dendroctonus valens)*	Scotch Pine	Some beetle activity on declining trees.	Wood County
Pine Spittlebug *(Aphrophora parallela)*	Scotch Pine	Forty acres thoroughly infested; all stems and branches covered in spittle. (*Spaheropsis* also present.)	Waupaca County
Armillaria Root Rot *(Armillaria mellea)*	Scotch Pine	Armillaria colonizing roots and root collar of declining trees.	Wood County
Balsam Gall Midge *(Paradiplosis tumifex)*	Balsam Fir	Light to moderate swelling of needles.	Eau Claire County
Winter Injury	Scotch Pine and Spruce	Browning needles.	Chippewa, Wood counties.
Lirula Needlecast Disease *(Lirula mirabilis)*	Balsam Fir	Widespread, scattered, moderate damage on native balsam with pockets of heavy damage in Christmas tree plantings.	Price, Rusk counties

CHESTNUT

Armillaria Root Rot *(Armillaria mellea)*	American Chestnut	General decline/death of mature trees. (Trees are growing in bottomlands).	Monroe County

ELM

Dutch Elm Disease *(Ceratocystis ulmi)*	Elm	Tree wilting, leading to death.	Dunn, Marathon counties.

MAPLE

Orange Humped Mapleworm *(Symmerista leucitys)*	Sugar Maple	Small pockets of near-total defoliation	Ashland, Bayfield counties

MISCELLANEOUS HARDWOODS

Fall Webworm *(Hyphantria cunea)*	Hardwoods	Widespread, spotty infestations caused defoliation.	Brown, Manitowoc, Marinette, Oconto, Outagamie counties
Fall Webworm *(Hyphantria cunea)*	Hardwoods	Light to moderate webbing and associated defoliation.	Scattered throughout WCR
Fall Webworm *(Hyphrantria cunia)*	Hardwoods	Widespread, light defoliation.	Entire NWD
Herbicide Injury	Various roadside trees	Damage to branches and saplings along roads. Hot weather during application may have allowed more drift than normal due to volatilization	Shawano County

Mountain Ash Sawfly (*Pristophora geniculata)*	Mountain Ash	Widespread moderate defoliation.	Burnett, Sawyer, Washburn counties

OAK

Oak Skeletonizer (*Bucculatrix ainsliella*)	Black oak	Large numbers of cocoon at end of first generation. No report of defoliation during second generation.	Adams County
Oak Wilt (*Ceratocystis fagacearrum)*	Red & White Oak Group	Red Oaks wilting leading to death. White oak showing symptoms of disease.	Throughout WCR. (Seemed to be a good year for oak wilt & more than usual).
Oak Tatters	Bur and white oak	Spring defoliation in two of the last three years has caused decline symptoms and scattered mortality of white oak.	Iowa, Dane and Jefferson Counties
Wool Sower Gall	White oak	Noticeable numbers of galls. Numerous reports. No noticeable damage to twigs.	Dane County
Botryosphaera Canker *(Botryosphaera spp.)*	Red Oak	Branch cankers and dieback.	Monroe County
Oak Tatters	White Oak	Leaf tissue missing between veins.	Trempealeau County
Oak Lace Bug *(Coryathuca arcuata)*	Burr Oak	Widespread, light to moderate bronzing.	Burnett, Washburn counties
Saddled Prominent	Pin and Red Oak	Twenty acres moderately defoliated in conjunction with variable oak leaf caterpillar and trumpet skeletonizer.	Marinette County

PINE

Red Pine Shoot Moth *(Dioryctria resinossella)*	Red Pine	Lateral branch shoot mortality. Trees did set new bud behind dead shoot.	Throughout WCR
Red Pine Decline/Mortality	Red Pine	General tree decline and crown thinning, leading to death - occurs in pockets.	Juneau, Trempealeau, Wood counties
Red Pine Shoot Moth *(Dioryctria resinossella)*	Red Pine	Moderate damage to plantations.	Green Lake and Marquette counties
Pine Bark Adelgid *(Pinus strobi)*	White Pine	Wilting and death of shoots and branches on understory regeneration in Jackson County. Trunks of mature pines covered with adelgids.	Jackson, Trempealeau, Wood counties
A Pine Pitch Midge (*Cecidomyia candidipes*)	White pine	Present in very low numbers in a Christmas tree plantation adjacent to jack pine.	Jackson County

Eastern Pine Shoot Borer *(Eucosma gloriola)*	Jack Pine	Lateral shoots and branches twisted and distorted. Branches broke off easily where they were damaged from the inside.	Juneau County
Pine False Webworm *(Acantholyda erythrocephala)*	Red Pine	Heavy defoliation and webbing of needles on branches. Only tufts of needles left at end of branches.	Portage County
White Pine Weevil *(Pissodes strobi)*	Jack Pine	Terminal leaders killed.	Juneau County
Ips Bark Beetles *(Ips spp.)*	Jack and Red Pine	Tree mortality.	Adams, Chippewa, Clark, Eau Claire, Jackson, St. Croix counties
Eastern Gall Rust *(Cronartium quercuum)*	Jack and Scotch Pine	Shoot and branch mortality to tree mortality.	Adams, Juneau, Wood counties
White Grubs *(Phyllophaga spp.)*	Red Pine Seedlings	Damage from feeding on roots caused reduced growth/vigor and mortality.	Monroe County
Jack Pine Budworm (*Choristonuera pinus*)	Jack Pine	Budworm numbers are low & hard to find.	Adams, Clark, Eau Claire, Jackson, Juneau, & Monroe counties
Armillaria Root Rot *(Armillaria mellea)*	Jack, Red and White Pine	General decline/death of trees.	Chippewa, Eau Claire, Juneau, Monroe counties
Pine Spittlebug *(Aphrophora cribrata)*	Jack and Scotch Pine	High number of spittlemasses on branches and trunks.	Adams, Juneau, Monroe, Wood counties
Pine Tortoise Scale *(Toumeyella parvicornis)*	Jack Pine	High number of scales on trees causing decline and mortality. Heavy sooty mold also present.	Wood County
Pine Root Collar Weevil *(Hylobius radicus)*	Red Pine	Feeding caused general decline.	Monroe County
Sphaeropsis Shoot Blight *(Sphaeropsis sapinea)*	Jack and Red Pine	Shoot mortality and branch flagging.	Adams, Dunn, Monroe, Wood counties
Sphaeropsis Shoot Blight *(Sphaeropsis sapinea)*	Austrian Pine	Severe infection (with cankers) of neighborhood trees in Green Bay.	Brown County
Zimmerman Pine Moth *(Dioryctria zimmermanni)*	Jack Pine	Some branch mortality and damage to main trunk.	Juneau County
Transplant Shock	Red Pine	Seedlings planted in spring had good shoot elongation, but had very few to no needles on shoots.	Monroe County
Saratoga spittlebug *(Aphrophora saratogensis)*	Red Pine	Scattered pockets of moderate to heavy damage.	Price County

SPRUCE

Spruce Budworm *(Choristoneura fumiferana)*	Spruce	Light to moderate defoliation. Egg mass survey indicates possible light defoliation in 1998.	Marathon County
Scale on Spruce Needles (Possibly Pine Needle Scale).	Spruce	Low number of scales present on needles. Needles and branches look healthy.	Marathon County
Yellow-headed Spruce Sawfly *(Pikonema alaskensis)*	White Spruce	Widely scattered pockets of moderate to heavy defoliation.	Bayfield, Douglas, Rusk, Sawyer, Washburn counties

Spruce Budworm *(Choristoneura funiferana)*	Spruce	Moderate defoliation of several white spruce plantations.	Washburn County
Spruce Budworm *(Choristoneura funiferana)*	Spruce	High populations damaged eighty acres of overmature and overstocked spruce at two sites.	Marinette County

WEATHER

Road Salt and Winter Injury	Red and White Pine	Browning of needles and general decline/mortality of trees along highways and roads.	Throughout WCR

WILDLIFE

Squirrels	Jack Pine	Bark stripped off of branches.	Adams County
Birds	Red Pine	Top-whorl lateral branches bent down and pulled out of socket.	Scattered throughout WCR
Hail Damage	Red Pine	Three acres damaged by localized hail.	Marinette County
Fertilization Injury	White Pine	Chlorosis and deformed growth on five acres of pole-sized trees; apparently associated with leachate from a neighboring hog feedlot.	Winnebago County

Appendix A
Jack Pine Budworm Survey Procedures & 1997 Survey Results

(Shane Weber, Forest Entomologist, DNR, Spooner, WI)

Jack pine budworm early larval survey

This survey is done on a yearly basis and is a key indication of the presence of destructive budworm populations. Thirty shoots and staminate flowers (15 of each) that can be reached from the ground are checked for larvae. Since staminate flowers are often scarce some years, a majority of shoots are usually used. A count of 20 or more infested shoots and flowers is considered sufficient enough to cause moderate to severe defoliation.

Table 1. Jack pine budworm early larval populations, 1997.

County	No. of Plots	No. of Infested Shoots	No. Infested Shoots/Plot	No. of High Plots	Percent High Plots
Polk	15	14	0.93	0	0
Burnett	23	18	0.78	0	0
Washburn	20	38	1.90	1	5
Douglas	51	553	10.84	31	60.8
Bayfield	28	376	13.43	19	67.9
Region	137	999	7.29	51	37.2

Table 2. Jack pine budworm early larval population trends, 1997.

County	No. Infested Shoots/Plot - 1996	No. Infested Shoots/Plot - 1997	No. Infested Shoots/Plot - % Change	Percent High Plots 1996	Percent High Plots 1997
Polk	1.27	0.93	-27	0	0
Burnett	1.43	0.78	-45	0	0
Washburn	1.55	1.90	23	0	5
Douglas	5.21	10.84	108	18.9	60.8
Bayfield	6.89	13.43	95	22.2	67.9
Region	3.95	7.29	85	11.6	37.2

Jack pine budworm late larval survey

This survey is done on a yearly basis as an indication of larval parasitism, since most parasitized larvae have died before reaching the fifth and sixth instars. Two 15 inch branches (needle bearing surface) are clipped from three trees, at mid-crown, from each plot. The larvae on each twig are counted and the total per tree is recorded. Three late instar larvae per 15 inch branch are considered a high population.

Table 3. Jack pine budworm late larval populations, 1997.

County	No. of Plots	Total Larvae	Larvae/Branch	No. of High Plots	Percent High Plots
Polk	15	10	0.11	0	0
Burnett	23	37	0.27	0	0
Washburn	20	137	1.14	1	5
Douglas	51	884	2.89	24	47.1
Bayfield	28	418	2.49	8	28.6
Region	137	1486	1.81	33	24.1

Table 4. Jack pine budworm late larval population trends.

County	Larvae/Branch 1996	Larvae/Branch 1997	Larvae/Branch Percent Change	No. of High Plots 1996	No. of High Plots 1997
Polk	0.20	0.11	-45	0	0
Burnett	0.14	0.27	93	0	0
Washburn	0.21	1.14	443	0	5
Douglas	1.61	2.89	80	11.3	47.1
Bayfield	1.73	2.49	44	17.9	28.6
Region	1.03	1.81	76	7.9	24.1

Jack pine budworm egg mass survey

This survey is conducted on a yearly basis and gives a fairly good indication of next year's population. Two 15 inch branches (needle bearing surface) are clipped at mid-crown from three trees at each location. Branches are examined for egg masses and numbers are recorded. Any area having more than three egg masses per plot, or .5 egg masses per 15 inch branch, has the potential for moderate to severe defoliation the next year.

Table 5. Jack pine budworm egg mass collections, 1997.

County	No. of Plots	No. Plots w/Masses	No. Plots w/Multiple Masses	No. Egg Masses	No. Hatched	Percent Hatched
Polk	15	0	0	0	0	0
Burnett	23	2	1	4	2	50
Washburn	20	4	3	9	7	77.8
Douglas	51	27	6	34	22.5	66.2
Bayfield	31	10	2	14	8	57.1
Region	140	43	12	61	39.5	64.8

Table 6. Jack pine budworm egg mass population trends.

County	Total Egg Masses 1996	Total Egg Masses 1997	Total Egg Mass Percent Change	Hatched Egg Masses 1996	Hatched Egg Masses 1997	Hatched Egg Masses Percent Change
Polk	2	0	-100	2	0	-100
Burnett	0	4	∞	0	2	∞
Washburn	3	9	300	2	7	350
Douglas	35	34	-3	26.5	22.5	-15
Bayfield	23	14	-39	16.5	8	-52
Region	63	61	-3	47	39.5	-16

Jack pine budworm pupal survey

Again, this survey is conducted on a yearly basis and gives a good indication of the kinds and numbers of pupal parasites in the population as well as next year's population of jack pine budworm. It is done in July when most insects are in the pupal stage. Some adults may already have emerged, but empty pupae cases rae collected and counted as emerged moths. At each stop, pupae are collected on a time basis. If five pupae are not found in five minutes, the collection is terminated. If five pupae are found in five minutes or less, the collection is continued until 25 pupae are found or until 15 minutes have elapsed. The time it took to find 25 pupae is then recorded. Later, adults, parasites, and non-emergence is recorded for each pupae.

Table 7. Jack pine budworm pupal survey, 1997.

County	Total Pupae	Total Minutes	Pupae /Min.	No. of Moths	% Moths	No. of Parasites	% Parasites	No. Non-emerged	% Non-emerged
Polk	2	75	0.03	0	0	1	50	1	50
Burnett	7	115	0.06	2	28.6	4	57.1	1	14.3
Washburn	75	121	0.62	34	45.3	31	41.3	10	13.4
Douglas	637	397	1.60	279	43.8	270	42.4	88	13.8
Bayfield	274	200	1.37	111	40.5	120	43.8	43	15.7
Region	995	908	1.10	426	42.8	426	42.8	143	14.4

Table 8. Jack pine budworm predator and parasite complex, 1997.

	Total	Percent of Parasites	Percent of Total
Itoplectes	202	47.4	20.3
Scambus	20	4.7	2.0
Phaogenes	42	9.9	4.2
Tachinids	92	21.6	9.2
Pteromalids	1	0.2	0.1
Predators	69	16.2	6.9

Table 9. Jack pine budworm pupal population trends, 1997.

County	Pupae/Min. 1996	Pupae/Min. 1997	Percent Change
Polk	0.13	0.03	-77
Burnett	0.07	0.06	-14
Washburn	0.16	0.62	388
Douglas	1.34	1.60	19
Bayfield	1.26	1.37	9
Region	0.91	1.10	21

Appendix B
Wisconsin Biocontrol Program for Gypsy Moth

Andrea Diss, Wis. Gypsy Moth Coordinator, Madison, WI

In 1997, gypsy moth were found in traps in every county in Wisconsin. Population increase was greatest in the Milwaukee area, the Lake Winnebago area, and the dry oak woodlands of Portage and Waushara counties. Results of surveys for other life stages verified the presence of many reproducing populations in these areas; populations were still too low to cause defoliation or even be easily found without the aid of pheromone traps.

Density of populations was high enough, however, to cause a shift in strategy in eastern counties from that of eradication, in an effort to slow the spread of this pest, to that of management, starting with quarantine and introduction of selected natural enemies. In 1997, four counties in northeast Wisconsin (Brown, Door, Kewaunee and Manitowoc) were placed under a regulation which requires that Christmas tree, forest and nursery stock products be certified free of gypsy moth before shipment into unquarantined areas.

Survey of Natural Enemies - Procedure

Prior to releasing non-native natural enemies of gypsy moth, entomologists from the Department of Natural Resources and the University of Wisconsin conducted surveys to determine which parasitoids and diseases were already present in the state.

Survey Type 1

A survey was conducted in order to look for organisms that attack the caterpillar stage of gypsy moth. Gypsy moth larvae were collected off foliage and from under bands of infested trees, and then reared to adulthood in the lab. It was determined whether or not natural enemies were the cause of death for those larvae that died prematurely. In 1996, 60 sites in northeast Wisconsin (Brown, Door, Kewaunee, Manitowoc, Marinette, and Oconto counties) were surveyed in this manner. In 1997, 35 sites in southeast WI (Milwaukee, Ozaukee, Washington, and Waukesha counties) were added to this survey.

Survey Type 2

Bioassays of soil samples were used to survey for the presence of *Entomophaga maimaiga* at the sites described above, in 1996 and 1997. In late May and early June, surface soil was collected from between the root flanges of preferred hosts. Soil samples were placed in 6x2x3 cm containers and third instar gypsy moths from a domestic colony were added. Larvae were maintained in the soil samples for ten days at 25° C, 40-65% RH and fed a standard artificial diet. Hemolymph of dead larvae were microscopically examined for the presence of *E. maimaiga* spores and other organisms.

Survey Type 3

Ooencyrtus kuvanae adults were recovered from egg masses collected as part of the annual gypsy moth monitoring program conducted by the Wisconsin Department of Agriculture, Trade and consumer Protection.

Survey of Natural Enemies - Results

Surveys show that a variety of non-native gypsy moth enemies are already present in WI, despite the rarity of their host (Figure 2). Most of these appear to have become established on their own, as a given species had either not been worked with in the past or had been introduced at a distance from where it was recovered.

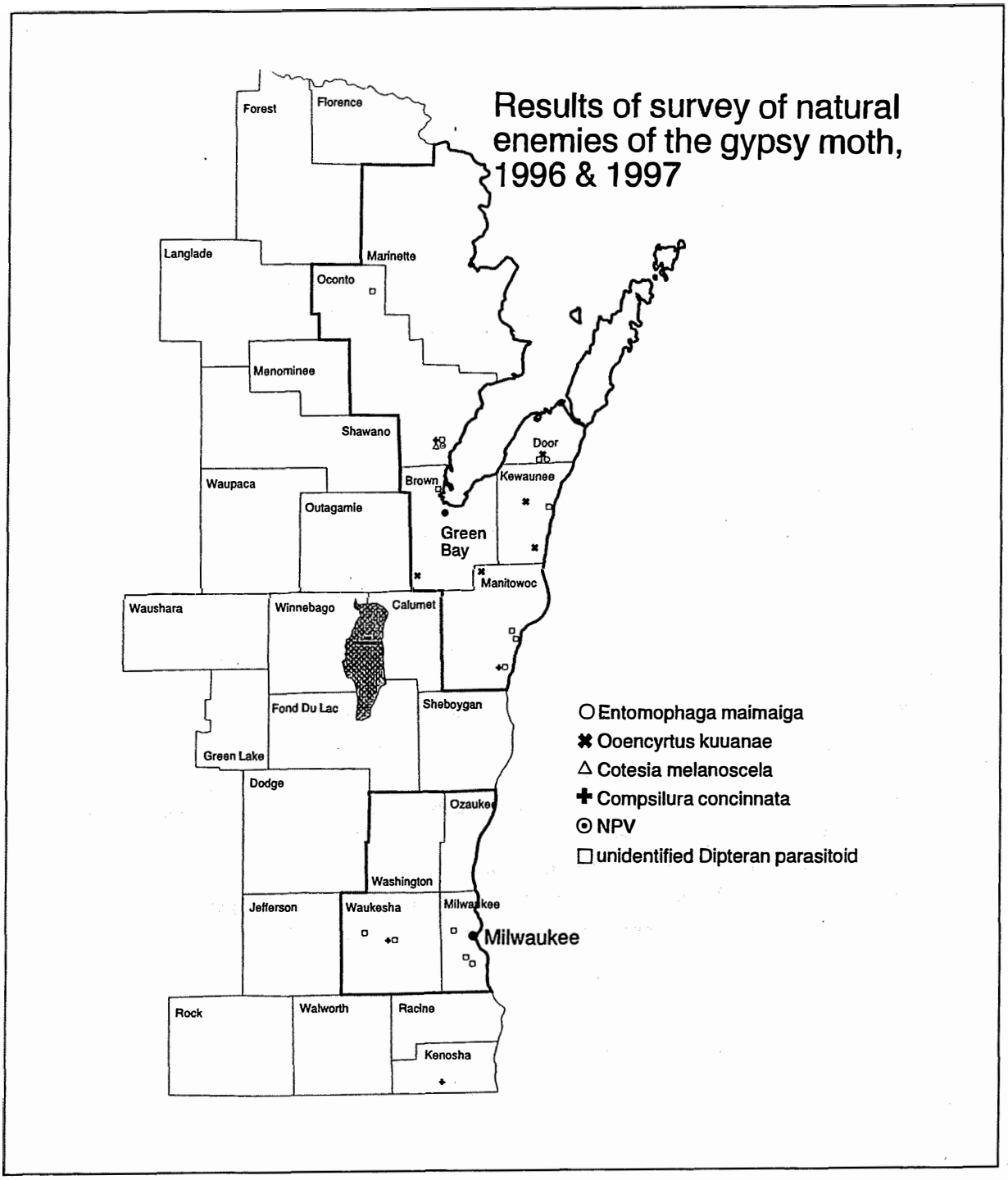

Figure 1. Results of survey of natural enemies of the gypsy moth in Wisconsin, 1996-1997.

E. maimaiga was discovered in a pre-pupa collected from a gypsy moth population at the base of the Door Peninsula; a population that has had the longest continuous history in WI. The discovery of *E. maimaiga* was particularly interesting since this species had not been previously introduced. There was no obvious means by which resting spores were transported from lower Michigan - the nearest established population of the fungus.

Cotesia melanoscela was found near the north shore of Green Bay at a site with the highest number of gypsy moths in the state. While *C. melanoscela* has been released previously in WI, all introductions were distant from this discovery site.

O. kuvanae was recovered throughout the base of the Door Peninsula, an area where gypsy moth was initially detected and which now hosts a peppering of small populations. Gypsy moth populations where *O. kuvanae* was found ranged from well-established, with 15-20 male moths per trap and 10+ egg masses, to surprisingly small, represented by only 1-3 males and one egg mass.

In the summer of 1997, NPV was found infecting stressed larvae that had defoliated a patch of shrubby willows. *Compsilura concinnata* was also present at this site and at many other sites, in both northeast and southeast counties, where gypsy moth is established. In addition to *C. concinnata,* a number of sites yielded as yet unidentified Dipteran parasitoids.

Introduction of Natural Enemies - Procedure

In the past two field seasons, the DNR has released three non-native natural enemies of gypsy moth (Figure 2). *E. maimaiga, O. kuvanae* and *C. melanoscela* were selected for their specificity, their demonstrated ability to establish in WI in very sparse gypsy moth populations, and their availability. Introductions of these three species is expected in future years, and as conditions become appropriate, additional species will be introduced as well.

Spores of *E. maimaiga* were released in 20 gypsy moth populations in northeast and southeast Wisconsin. Unlike other artificial introductions of this fungus, imported forest soil was not used as inoculum. Instead, with the generous help of Lea Bauer and Noah Koller (USDA Forest Service NCES, MSU, East Lansing, MI), dried cadavers of gypsy moth killed by *E. maimaiga* were collected in MI. Cadavers were ground into a coarse powder and then mixed with sterilized soil from WI. The number of spores introduced at each site was estimated based on the number of cadavers per volume of powder, assuming one million spores per cadaver. At each introduction site, the spore-soil mix was evenly distributed at the base of ten favorable host trees. In June of 1998, the inoculated trees will be revisited. Burlap bands will be placed around them and gypsy moth larvae will be collected. Larvae will then be reared out to determine if they have become infected with the fungus.

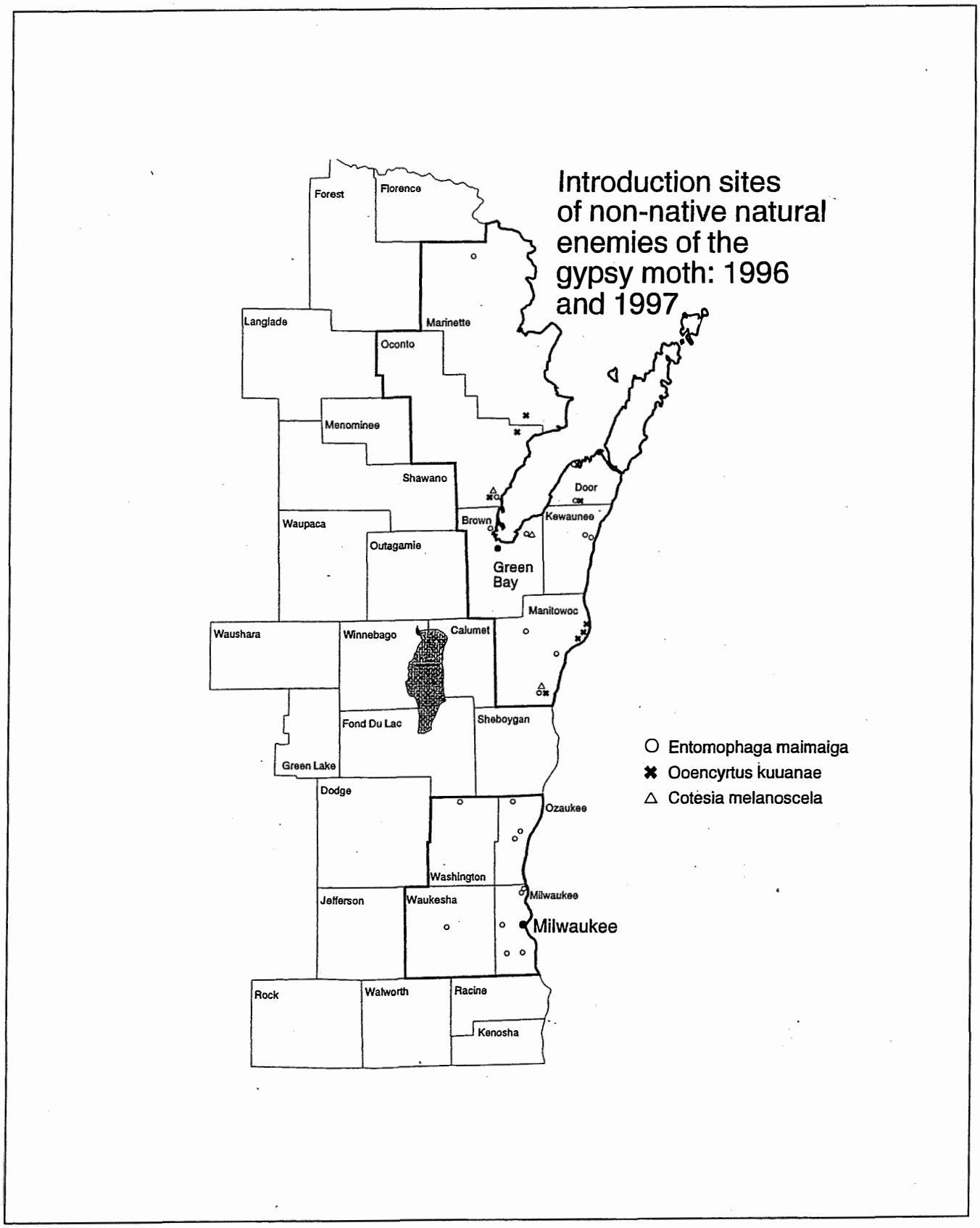

Figure 2. Introduction sites of non-native natural enemies of the gypsy moth in Wisconsin, 1996-1997.

O. kuvanae was introduced to gypsy moth populations outside the Door Peninsula in order to assist in the spread of this egg parasitoid. In addition, a previously colonized site was supplemented in an effort to establish a higher density population of the wasp, which could be collected from for future introductions. Adult *O. kuvanae* was introduced in October of 1996. Wasps were collected as they emerged from infested egg masses, which were supplied by the MI Department of Agriculture. Additional introductions of *O. kuvanae* were planned for 1997, but unfortunately, the MI Dept. of Ag. was unable to supply the infested gypsy moth egg masses. It is also unfortunate that the wasp was unrecoverable from sites where it had been introduced in 1996. However, the probability of recovering a rare parasitoid from a scarce host is very low and this result should not be considered particularly discouraging. All introductions are followed by a post-release survey the following summer, and released species are hoped to be recovered in 1998.

C. melanoscela was introduced into three sites in 1997. Pupae of the French strain were supplied by Roger Fuester from the USDA Beneficial Insects Research Lab in Newark, DE. In October, pupae were glued to cardboard discs and the discs were then attached to trees supporting gypsy moth egg masses. In June of 1998, discs will be collected and the number of successfully emerged *C. melanoscela* will be determined. Gypsy moth larvae will also be collected at the release sites and reared out to determine if they have become parasitized.

Appendix C
Silviculture of Butternut: Relationship Between Size of Canopy Opening, Disease Development and Host Survival

Jane Cummings Carlson, Forest Pathologist, Madison, WI 53711
(Conducted on the Menominee Indian Reservation, northeastern Wisconsin)

Introduction and Objectives

In a 1992 survey of butternut in 32 counties in Wisconsin, 91% of the 1,394 trees surveyed were infected with a canker-causing fungus, *Sirococcus clavigignenti-juglandacearum.* Twenty-seven percent of the trees surveyed were dead. Only 6% of the trees had basal sprouts and 65% of the sprout clumps were cankered. Maintenance of butternut in Wisconsin as a component of our forests must now focus on whether or not butternut can survive to a seed-bearing age, if given good to excellent growing conditions. Butternut is known to be shade intolerant and able to grow on sites ranging from dry-mesic/nutrient medium to mesic/nutrient-rich. Regenerating butternut on the best sites will promote faster growth; fast-growing butternut has a better chance of reaching a seed-bearing age before the canker can kill the tree.

The objectives of this study were to:

1) Evaluate the survival and growth of planted butternut in various sized canopy openings on 2 habitat types.
2) Test the hypothesis that butternut can survive to a seed-bearing age (even if infected with butternut canker) if planted on habitat types best suited for growing butternut.
3) Increase our understanding of the silviculture of butternut and refine the silviculture guidelines for butternut based on the study results.

Methods

Five different sizes of canopy openings were chosen for evaluation: .03 a, ¼ a, ½ a, 1 a, and 2 a. Two habitat types were chosen for evaluation: AQVib (Acer-Quercus/Viburnum) and ATF (Acer-Tsuga-Fagus/Dryopteris). Each size canopy opening was replicated 3 times on each habitat type (5 size openings X 2 habitat types X 3 replications = 30 plots). AQVib is a dry-mesic, nutrient-medium sandy loam or loamy sand site. Climax species are sugar and red maple, red oak, basswood and white ash. ATF is a dry-mesic to mesic, medium to rich nutrient, sandy loam, loam, or loamy sand site. Climax species are sugar maple, hemlock and yellow birch.

In 1994, the canopy openings were created. All trees and woody material >2" in diameter were removed. No herbicides were applied. The nursery that supplied the butternut seedlings also had a supply of buartnuts (hybrids between heartnut and butternut). Buartnuts are known to be resistant to butternut canker. It was decided to test this in the field and plant a few buartnuts in the plots. In the spring of 1995, 1-0 butternut and buartnut seedlings were planted into the plots (Table 1) .

Table 1. Butternut and buartnut seedlings planted in various plots - Menominee Indian Reservation, spring 1995.

	Plot Size	Buttnernut Seedlings (No.)	Buartnut Seedlings (No.)
	2a	56	8
	1a	56	8
	1/2a	56	8
	1/4a	20	8
	.03a	12	0
Total		200	32
Total on all plots		1,200	192

The butternuts were planted at a 10' X 10' spacing except the .03 acre plot. These were planted at an 8' X 8' spacing. The buartnuts were planted in an east-west line north of the butternut plots at a 10' spacing. This line was shifted east and west to fit in areas not full of slash but was always kept north of the butternut.

Data Collection

In November, 1995, a survey was conducted of the area surrounding the butternut plots. An area covering 200' in all directions from the plots was surveyed for the presence of butternut trees. Fourteen butternuts were observed within 200' of the plots on the AQVib habitat type (Table 2, Fig. 1); no butternut trees were observed surrounding the plots on the ATF habitat type. This survey was conducted to determine the potential for various levels of disease pressure on the 2 habitat types.

Table 2. Diameter and canker status of butternut trees within 200' of the silvicultural trial plots on the Menominee Indian Reservation, AQVib habitat type.

TREE #	DBH (")	CANKER STATUS
1	2.5	possible twig canker
2	4	cankered
3	10	cankered
4	4	cankered
5	5	cankered
6	8 (triple stem)	cankered
7	2	cankered
8	10	cankered
9	5	cankered
10	5	cankered
11	8	cankered
12	10	cankered
13	5	not cankered
14	8	cankered

Data regarding the height, diameter and health of the planted seedlings were collected when the trees were planted (spring of '95); at the end of the first growing season, (fall of '95); and at the end of the second growing season (February, '97). Each year, when data are collected, all woody vegetation shading the butternut seedlings from above is removed.

An unusually high amount of mortality was observed at the end of the first growing season (Table 3). Thus in 1996, new 1-0 butternut seedlings were planted in spots where seedlings had died. Mortality was higher on the AQVib site. The dead seedlings were too deteriorated to draw any conclusions regarding the cause of mortality. Average height growth was negative due to feeding by white-tailed deer.

Table 3. Average diameter and height growth and percent mortality of butternut seedlings, September, 1995 (5 months after planting), Menominee Indian Reservation, WI.

	Site 1 - AQVib			**Site 2 - ATDF**		
Plot Size (ac)	Diameter Growth (mm)	Height Growth (cm)	Percent Mortality	Diameter Growth (mm)	Height Growth (cm)	Percent Mortality
0.03	0.5	-0.1	27.8	0.5	0.7	27.8
0.25	0.2	-7.5	38.3	2.8	1.3	28.3
0.5	0.7	-1.8	32.1	2.6	1.8	27.8
1.0	0.7	-6.8	48.8	1.6	1.4	29.2
2.0	1.0	-6.5	43.8	2.0	1.4	23.4

A summary of the height and diameter data is shown in figures 1-4. Average height and diameter of the seedlings on the ATF is generally higher than seedlings on the AQVib site. This is the better habitat type yet the data are influenced by the high mortality on the AQVib site followed by a replanting in 1996. A high percentage of the seedlings on some of the AQVib sites are one year younger than the seedlings on the ATF sites. Thus, it is a bit early to draw conclusions from the data.

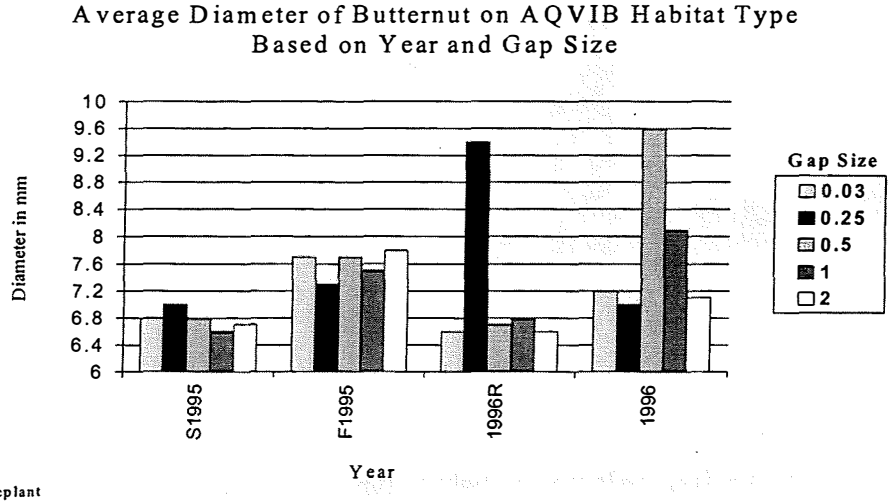

Figure 1. Average diameter of butternut seedlings planted on habitat type AQVib silvicultural plot, Menominee Indian Reservation, WI, 1995-1996.

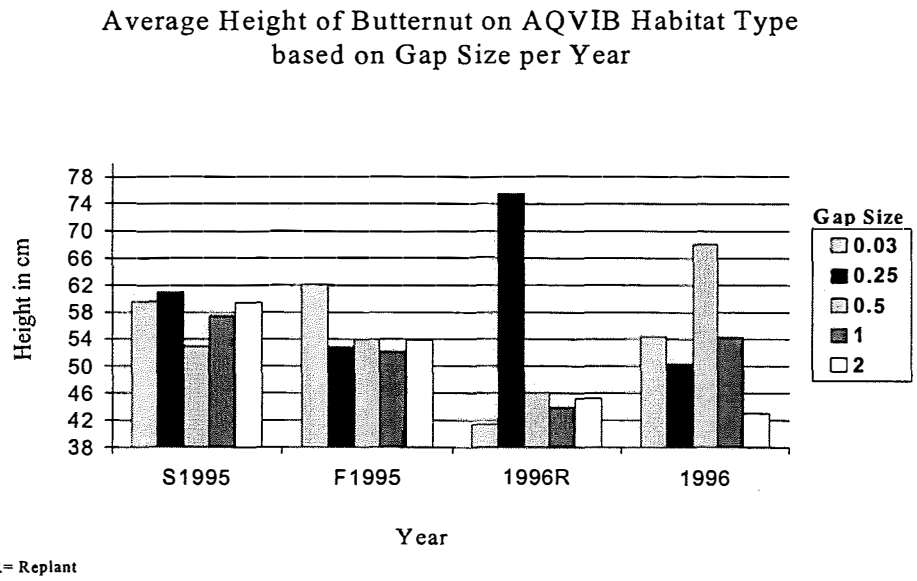

Figure 2. Average height of butternut seedlings planted on habitat type AQVib silvicultural plot, Menominee Indian Reservation, WI 1995-1996.

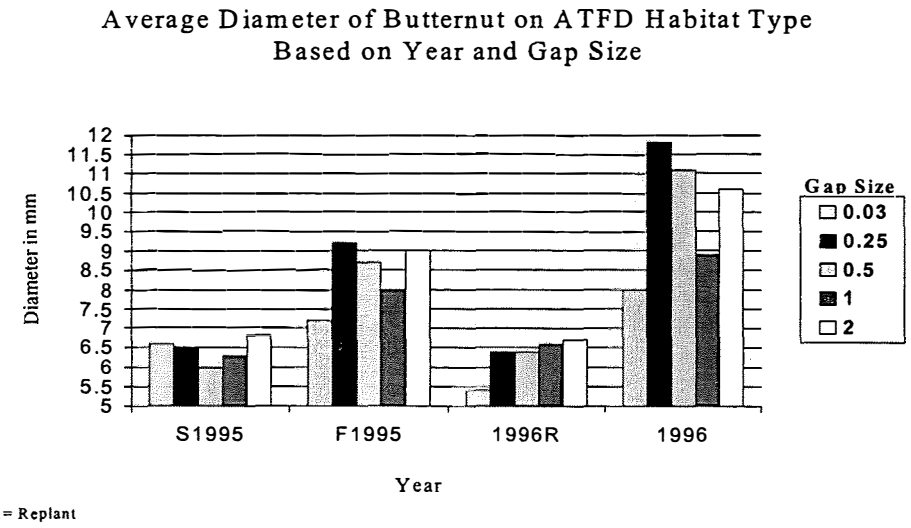

Figure 3. Average diameter of butternut seedlings planted on habitat type ATFD silvicultural plot, Menominee Indian Reservation, WI, 1995-1996.

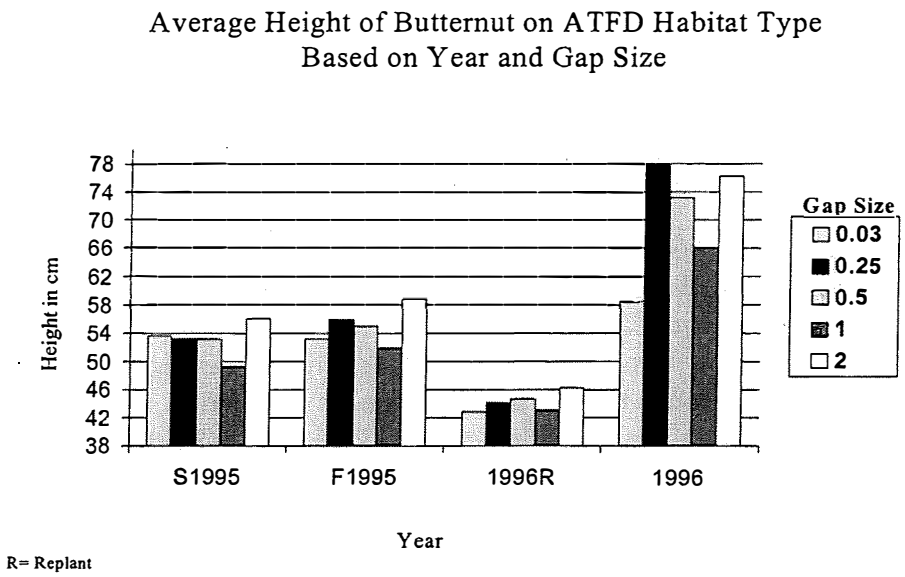

Figure 4. Average height of butternut seedlings planted on habitat type ATF silvicultural plot, Menominee Indian Reservation, WI, 1995 - 1996.

Interim Summary

In general, the butternut seedlings growing on the better habitat type (ATF) are larger in diameter and height than the seedlings growing on AQVib. The high mortality and replant rate on the AQVib site has a large influence on the data thus it is too early to draw conclusions from this data. To date, no butternut cankers have been observed on any of the seedlings. Deer tend to frequent the openings and antler-rubbing injury has been observed on numerous seedlings. The deer tend to choose the larger seedlings to rub their antlers on. Some browse injury has also been recorded.

Within habitat types, the size of the opening does not appear to have a major influence on height or diameter yet. The size of the opening may have a greater influence on whether or not deer are attracted thus may be an important connection in this study.

Data collection will continue annually through the year 2000. Data will then be collected every 5 years until the year 2015.

Appendix D
Biological Control of Chestnut Blight
in Wisconsin (1987-1997)

Jane Cummings Carlson, Forest Pathologist, Madison, WI
and Dr. William MacDonald, Professor, Univ. of West Virginia, Morgantown, WV

Introduction

A unique stand of American chestnut covers approximately 160 acres of rolling hills in LaCrosse County, western Wisconsin. The stand originated some time during the late 1800's when a Farmer, Martin Hicks, brought American chestnut seeds from Pennsylvania. Mr. Hicks planted the seeds in hopes of creating a fence row. Little did he know he planted the seeds that initiated the largest (currently) known stand of American chestnuts in the United States. Since the late 1880's, American chestnut has seeded in and become the dominant (in numbers and crown class) species on this property. Over 2,500 trees (>5" dbh) have been observed on this land (Fig. 1). Other common species are bitternut and shagbark hickory, white birch, northern red and white oak and basswood. The state record American chestnut also resides on this property.

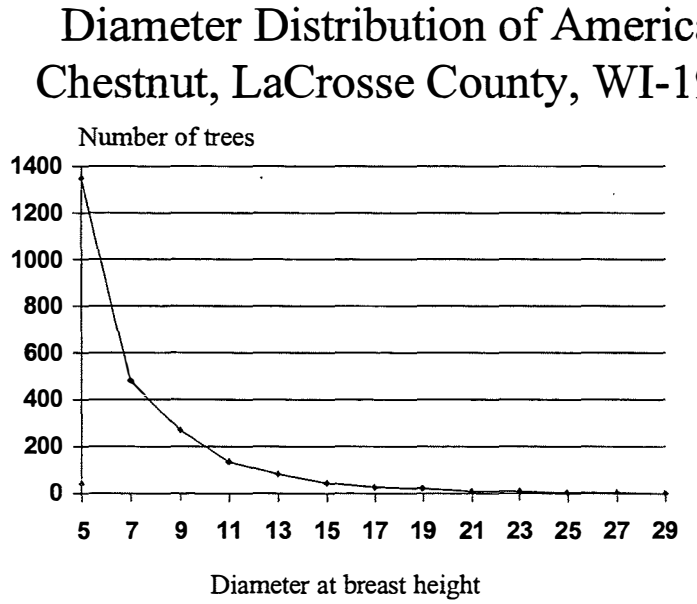

Figure 1. Diameter distribution of American Chestnut, LaCrosse County, WI, 1990.

Survey History

Each year, since 1990, a 100% survey of this stand has been conducted. The purpose of the survey was to detect the number and location of newly infected trees (Figure 2). Data regarding the size of the newly infected trees and more recently, their location (via GPS) were recorded. The maps showing locations of infected trees were extremely helpful when crews were trying to locate trees during inoculation and sampling efforts. Crown dieback measurements were also collected on infected trees from 1995 - '97 (Fig. 3). Crown dieback increased in several categories in 1996. This is due largely to a severely cold winter where temperatures of -40 degrees Fahrenheit were recorded.

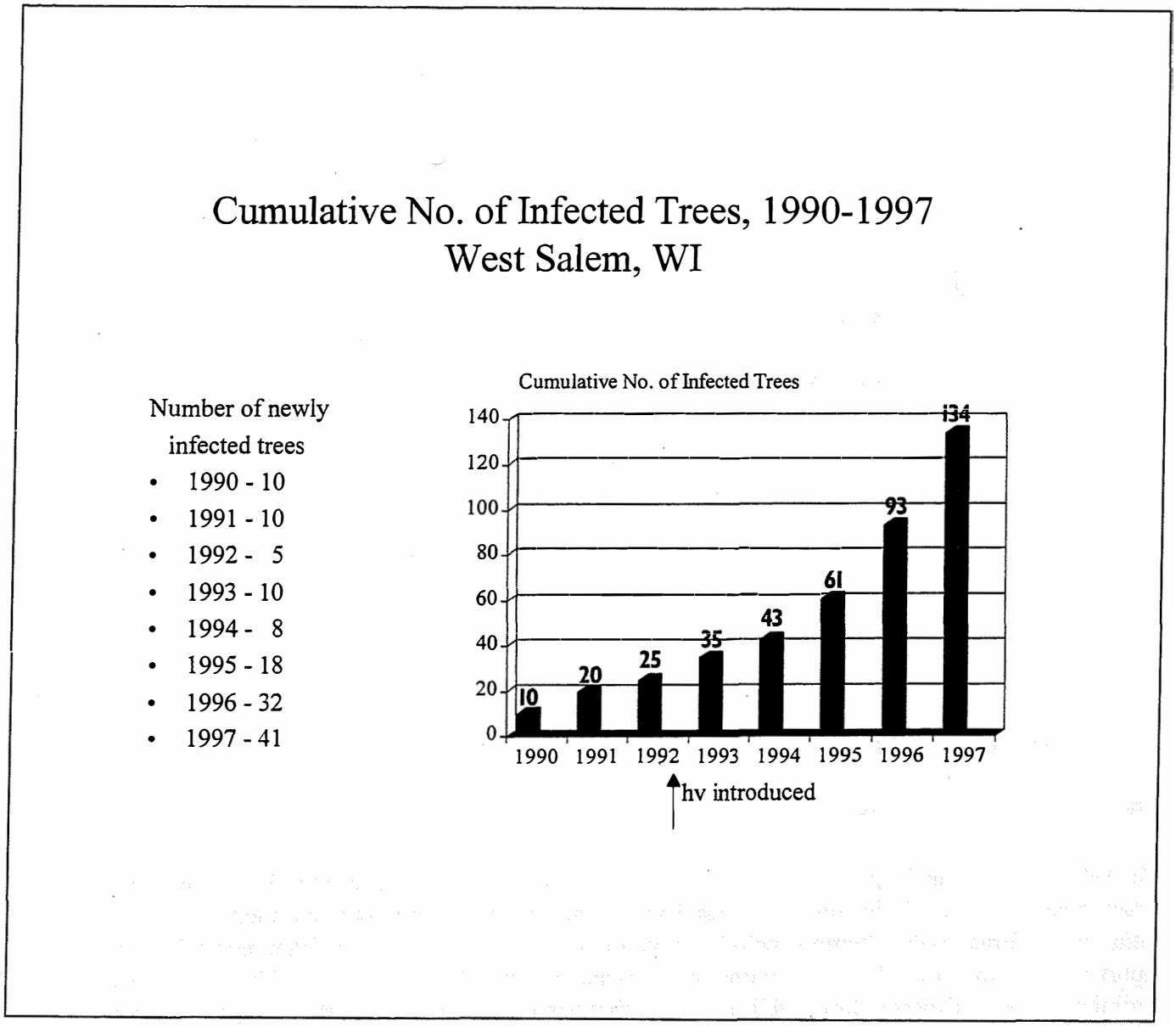

Figure 2. Cumulative number of American chestnut trees infected with *Cryphonectria parasitica* (1990 - 1997).

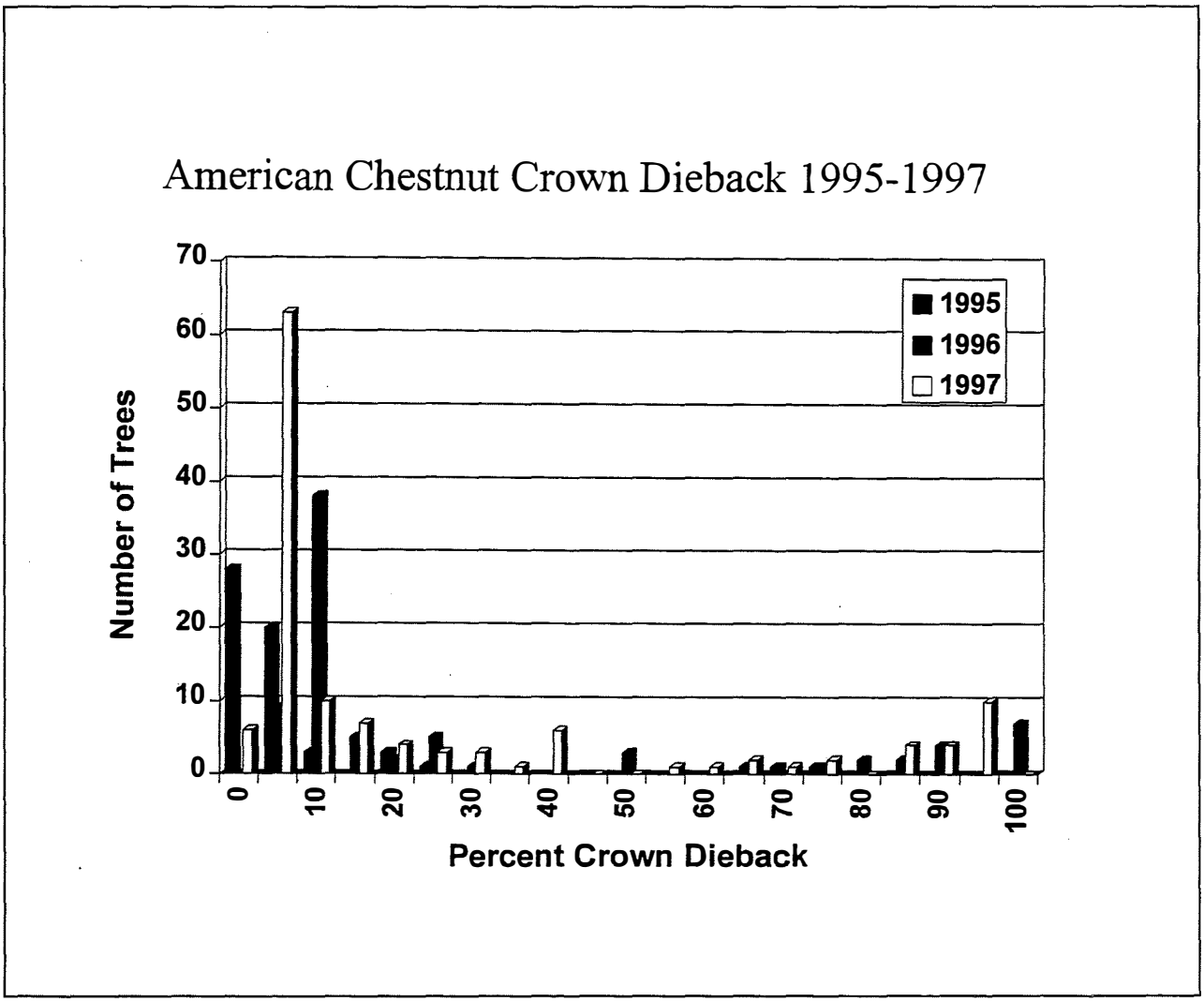

Figure 3. Percent crown dieback of American chestnut infected with *Cryphonectria parasitica*, 1995 - '97.

Disease Management History

Eradication and soil compresses

In 1987, the chestnut blight fungus *(Cryphonectria parasitica)* was observed killing approximately 4 American chestnuts on this property. For 3 years, various disease management methods were employed. Eradication attempts included covering all infected trees with a foam, normally used to prevent structures from burning, felling the trees and burying them on the site. The foam was used to minimize spore dispersal during felling. Trees that had cankers present at the root collar only were treated by covering the cankered areas with a mixture of manure and soil (soil compress). The mounded mixture was covered with plastic and secured with tires. This is a disease management method that utilizes soil organisms as biocontrol agents; these agents slow the growth of *C. parasitica.* After 3 years, these methods appeared to be providing little if any disease management, thus a new approach was initiated.

Hypovirulence

In 1991, scientists from Cornell University, Michigan State University and West Virginia University (WVU), proposed introducing a hypovirus into the stand to slow the growth of the pathogen. The success of hypoviruses or hypovirulence has been varied yet the Wisconsin situation appeared ideal for its success. Isolates of the pathogen revealed only one strain of the fungus was present in the stand. This lack of genetic diversity in the pathogen created an ideal situation for introduction of one biocontrol agent and insured compatibility in the field. If the pathogen had been genetically diverse, multiple types of hypoviruses would have been required. Isolates of the pathogen were sent to WVU and a hypovirus occurring naturally in Michigan, was transmitted into the Wisconsin pathogen.

In the spring of 1992, '93 and '94, approximately 186 cankers were treated with the hypovirus. Cankers were treated by removing bark plugs (with a leather punch) from the canker margin and introducing a thick slurry of the hypovirus. In 1994, treated cankers were sampled[1] to determine the success of the hypovirus transferring to the pathogen and surviving. Of the treated cankers (1992 & '93), only 30% of the samples revealed the presence of the hypovirus; 11% of the isolates from newly formed (never treated) cankers contained the hypovirus. In 1995, the evaluation continued and revealed only a slight increase (36%) in the percent of isolates containing the hypovirus. Possible explanations for the low rate of hypovirus recovery include the following:

1) The Michigan hypovirus greatly reduces the virulence of the West Salem strain, thereby reducing its ability to invade bark, sporulate and thus perpetuate itself.
2) Only 2% of the asexual spores contain hypovirus, further limiting hypovirus establishment.
3) The thread-like filaments of *C. parasitica* causing the canker may be discontinuous in the older thick-bark trees so that spread of the hypovirus throughout the canker from our points of introduction was limited.

This low rate of hypovirus transmission lead to the introduction of a hypovirus of European origin. The European hypovirus is known to be less debilitating and be transmitted to more than 95% of asexual spores. In 1995, '96, and '97, the new hypovirus was introduced into all new cankers and any cankers that appeared to be "breaking out" or growing beyond the point of previous treatments. Sampling also continued (of all cankers) during this three year period. The European hypovirus appears to be moving more readily through the stand than the Michigan hypovirus. The 1997 samples revealed 38% of isolations (collected in 1996 & '97) contained the European hypovirus; 15% contained the Michigan hypovirus. Thus, approximately half of all isolations from the cankers contain the pathogen, infected with a hypovirus.

In 1996, another strain of the fungus was isolated from a small group of trees located on the far western side of the property. Unfortunately, laboratory tests have shown that this isolate is sexually compatible with the first isolate. If the two isolates reproduce sexually, which is inevitable, an increase in the genetic diversity of their offspring is expected. Also, sexual reproduction can result in the production of wind borne spores, which will speed the spread of the disease.

[1] Samples were collected by removing 8-12 small bark samples per canker; a bone marrow biopsy instrument is used as the sampling tool.

Summary

For six years, a hypovirus has been inoculated into all known infected trees. All infected trees have been monitored for the development of wound or callus tissue and have been sampled for the presence of hypoviruses. The hypoviruses are established in the stand of trees and are beginning to spread on their own. Many of the treated cankers appear to be in remission while others seem to be unaffected. It is still unknown whether or not the hypoviruses will significantly slow disease development. The pathogen is expected to continue to spread in the stand and cause some mortality. Hopes are for the hypoviruses to influence disease development to a point where American chestnut can remain a significant component of the stand for decades to come.

Appendix F
Forest Health Monitoring
(Background and 1998 Activity)

Teague Prichard, Wisconsin DNR, Air Management, Madison, WI

The Forest Health Monitoring (FHM) program is a cooperative, multi-agency, national effort to monitor, assess, and report on the long-term status, changes, and trends in forest ecosystem health in the United States.

The program developed from growing environmental concerns about air pollution, acid rain, global climate change, population growth and long-term resource management on our forest resources. In response to these concerns federal and state agencies have fostered a cooperative effort to develop and implement a comprehensive program for monitoring the status and trends of forest ecosystem health.

The FHM program is comprised of three inter-related monitoring activities:

- **Detection Monitoring**
- **Evaluation Monitoring and**
- **Intensive Site Ecosystem Monitoring**

To date, the majority of the FHM activities have focused on detection monitoring. Evaluation monitoring will be implemented for the first time in 1998.

Detection Monitoring is the most extensive of FHM's three monitoring activities. It is designed to provide data to determine base line or current conditions of forest ecosystems, and detect changes and trends over time. This information is analyzed to determine if detected changes are anticipated, and if those changes indicate improving forest health or are cause for concern, warranting additional evaluation. Detection monitoring covers all forested lands and has two components. Together these components describe forest health;

(1) ***the plot component***, which are measurements made on the FHM network of permanent plots; and

(2) ***the survey component***, which is forest surveys of insects, disease and other effects causing stress, conducted independently of the FHM plot component.

The Plot Component

The basis for the FHM plot component is a network of permanent plots distributed on a systematic grid across the entire U.S. Measurements or groups of measurements called indicators are collected yearly on the plots. An indicator is defined as any biological and non-biological component of the environment that quantitatively estimates the condition or change in condition of ecological resources, the magnitude of stress, or the exposure of a biological component to stress. The current set of indicators being measured in the plot component of detection monitoring include: mensuration, crown condition, damage assessment, ozone bioindicator plants, vegetation diversity, lichens, and soils.

The Survey Component

The symptoms of natural and human-caused stressors that affect forests are detected and measured with aerial and ground surveys. Important stressors are insects, diseases, climate changes, extreme weather, and air pollution. Commonly measured symptoms include defoliation, foliage discoloration, tree dieback, branch breakage, main stem breakage, uprooted trees, and tree mortality.

Program History - National and Wisconsin

Forest Health Monitoring began in 1990 in six New England states (Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island. Plot component indicators measured were ozone bioindicator plants, crown condition, tree damage, tree mortality, and tree regeneration. Six states were added in 1991 (New Jersey, Delaware, Maryland, Virginia, Georgia, and Alabama). California and Colorado were added in 1992 and measured additional indicators including soils, photosynthetically active radiation (PAR), lichen communities, one hectare mortality assessments and vegetation structure and plant diversity. In 1994, the lake states (Wisconsin, Minnesota and Michigan) were added to the program. Plot component indicators measured for Wisconsin include: ozone bioindicator plants, crown condition, tree damage, tree mortality, and tree regeneration. In 1997, lichen and soil indicators will be added. West Virginia and Pennsylvania joined the program in 1995 and Indiana was the only state added in 1996.

Organization and Implementation of the Plot Component in Wisconsin

Under the auspices of the USDA Forest Service –Northeastern Forest Experiment Station and Northeastern Area State and Private Forestry, the Wisconsin Department of Natural Resources is responsible for implementing all aspects of the FHM program for Wisconsin. For the plot component, the Bureau of Forestry and Bureau of Air Management work cooperatively to implement the field activities, develop program directions, and promote the forest health concept. The Lumberjack Resource Conservation and Development, a not-for-profit agency located in Tomahawk Wisconsin, is responsible for collecting the field plot data.

Data is collecting during the summer months by a two-person field crew. Wisconsin DNR and the US Forest Service are responsible for conducting field checks to verify the accuracy of the data being collected. All data is submitted to the Forest Service for analysis.

Funding

Funding for the program is distributed through the Northeastern Forest Experiment Station. The detection plot work is funded through an 80:20 federal/state cost share cooperative agreement. The USDA Forest Service covers 80% of the costs and Wisconsin provides 20% of the costs. Wisconsin's costs include equipment, reduction in overhead and staff time.

FHM Plot Component

The plot component is the backbone of the FHM program. The objective of the plot component is to monitor, assess and report on the long-term status, changes and trends in forest ecosystem health on a regional and national basis. Monitoring can be defined as the repeated measurement or sampling of information for comparison to a reference system or identified baseline. It always involves the determination of changes over time, usually interpreted against a baseline. The FHM plot component is designed to collect the appropriate indicators of health over time. The plot component

is based on a set of permanent plots distributed systematically over the landscape and evaluated on a yearly basis.

FHM Plot Design

Each FHM plot has four fixed-area, circular subplots (Figure 1). Subplot centers are spaced 120 feet (36.6m) apart. All subplots are 1/24-acre (1/60 hectare) in size and contain a micro-plot offset 12 feet (3.7m) from the subplot center. The micro-plots are 1/300-acre (1/750-hectare) in size.

Most tree measurements are taken within the subplots. Seedlings and saplings are measured on the micro-plots. Annual plots are used for the tree measurements that require collecting a physical sample. This allows the subplots to remain unaltered by sample collection.

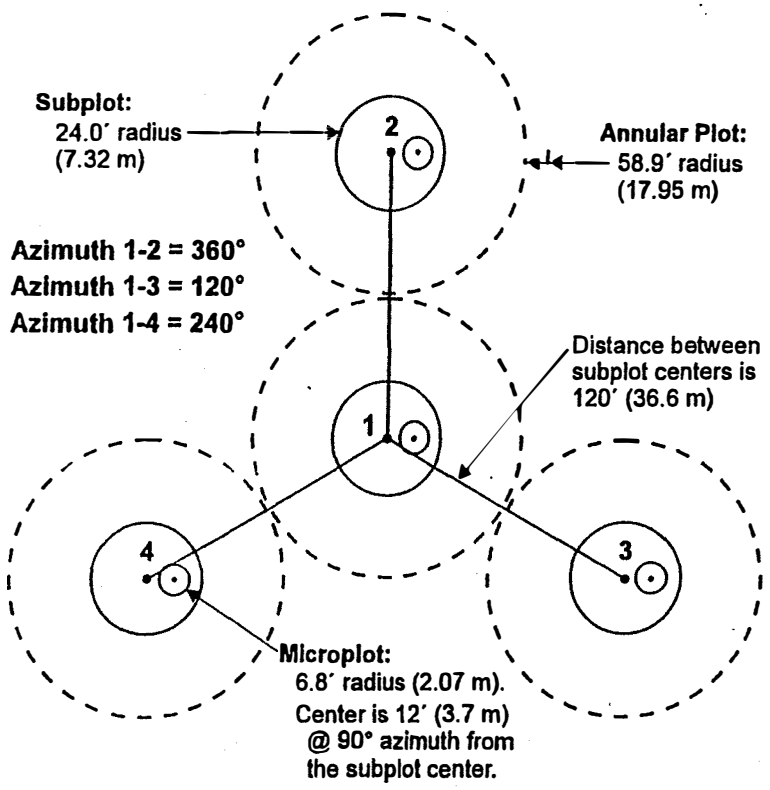

Figure 1-1 National FHM plot layout is designed around four points (subplot centers).

Figure 1. FHM plot design.

FHM Sampling Design

The FHM sampling design is a spatially and temporally systematic sample on a national hexagonal base grid located 27 km apart. The sampling design minimizes the number and frequency of plot visits without reducing precision to an unacceptable level.

Rotating panel and interpenetrating design are related and non-interchangeable terms describing the FHM design. Rotating panel means that a specific group of plots (a panel) is measured at a specified frequency (for example, every four years). Interpenetrating design describes how the plots are grouped into panels - the FHM plots in any panel are chosen so they are uniformly distributed within the monitoring area. Each level - the base grid, the panel, and the overlap - is an equal area sample of the same geographic area. This means that for a given level, each plot represents the same number of acres. All plots are equidistant from all adjacent plots.

Forested plots on the base grid are measured on a four-year cycle with 1/4 of the plots (called a panel) measured every year. In addition, 1/3 of the plots from the previous years panel (called the overlap) are measured. This overlap is 1/12 of the base grid. When the design is implemented for the first time, all plots are established and measured the first year. This complete measurement provides an estimate of initial status and improves precision in estimating change in forest health within two years after the entire base grid is established.

The design can be easily modified to meet more stringent or less stringent data requirements as program objectives evolve. For example, the sample size can be increased either permanently or temporarily in geographic areas that have high levels of biological or anthropogenic (human-caused) stress. In states where policy decisions require greater precision than that provided by the national grid, the sampling intensity can be increased in that state without losing compatibility with other states.

Forest Health Indicators - Definitions and Regional Results

Crown Ratings

Crown evaluations indicate tree condition by indirectly assessing an individual tree's ability to capture light and produce carbohydrates by photosynthesis. Six measurements are made for the trees crowns; crown diameter, live crown ration, crown density, crown dieback, crown transparency and crown vigor. These measurements, except for crown vigor, are made on all live trees 5.0 inches diameter at breast height and larger. The measurements for live crown ration, crown density, crown dieback and crown transparency are assigned range from 0 to 100 percent, by 5 percent classes. FHM field crews collect crown data during the normal field season which begins in early June and ends in early September.

> **Crown Diameter** is two measurements, one at the widest point and a second diameter measurement made 90 degrees to the diameter at the widest point. If viewed from the air, the crown diameter is the average of an oval including all foliage.
>
> **Live Crown Ration** is the percentage of height which supports live, green foliage that is contributing to total height growth.

Crown Density is a measure of how complete an individual tree crown is when compared to a full-crown outline (Figure 2). Crown density represents the amount of foliage, reproductive structures (seeds and cones), and branches that obstruct skylight visibility through the crown. Trees with high scores for crown density generally have high potential for survival and reproduction. Crown density values greater than 20% indicate more active crown areas and healthier trees, values less than 20% indicate poor crown condition.

Crown Dieback is the percentage of recent branch mortality that begins at the terminal portion of branches and proceeds toward the trunk, excluding portions caused by natural shading or competition (Figure 2). Dieback is caused by severe shock to root systems, drought or disease. Some species show natural light dieback as part of normal growth.

Foliage Transparency is an indicator of light filtering through needles and leaves in the upper one-third of the crown (Figure 2). Transparency values differ by species and depend on natural branching habit and foliage orientation. High transparency values (>50%) indicate unhealthy crown conditions. Reduce foliage can be caused by insects disease and other stressors.

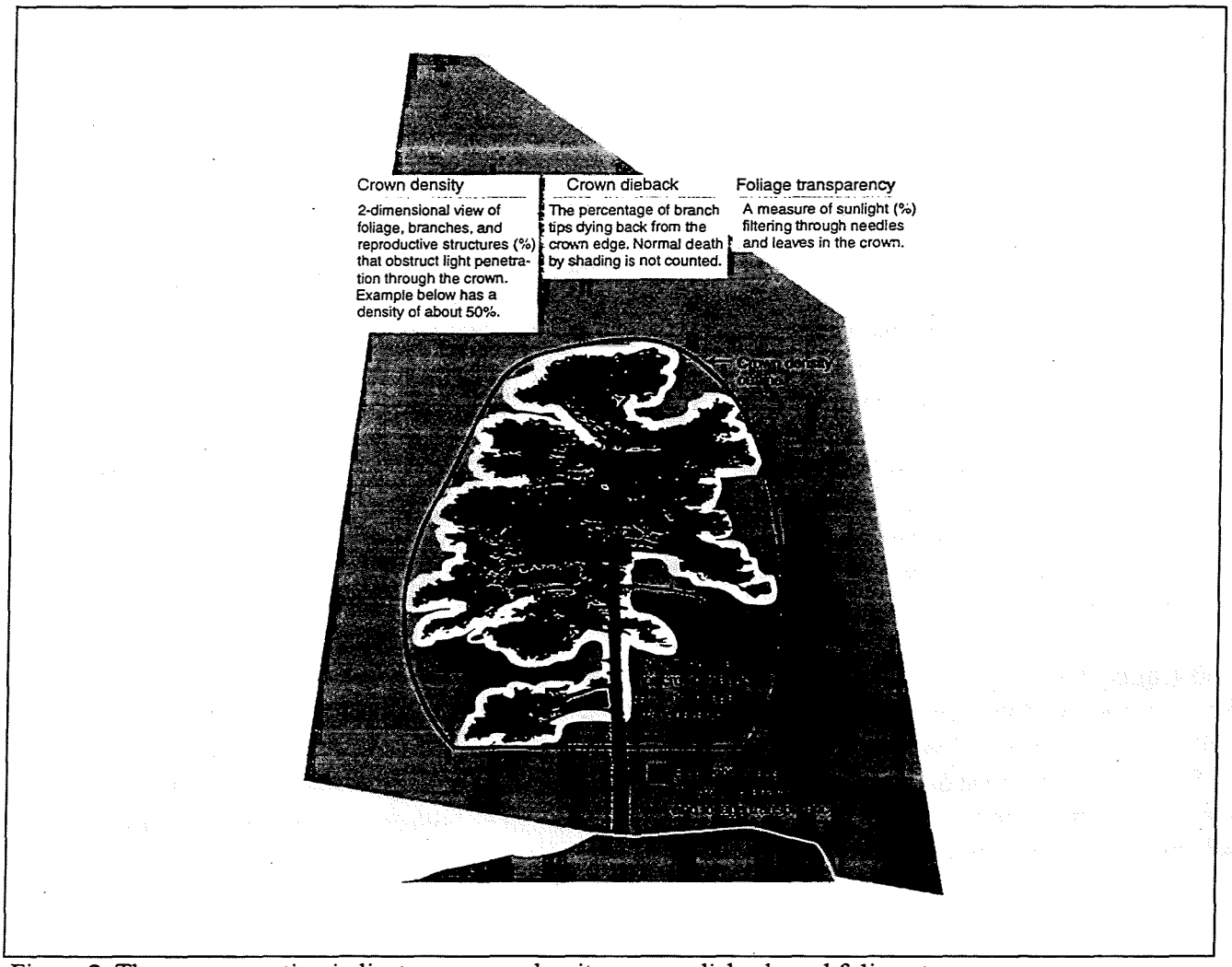
Crown density
2-dimensional view of foliage, branches, and reproductive structures (%) that obstruct light penetration through the crown. Example below has a density of about 50%.
Crown dieback
The percentage of branch tips dying back from the crown edge. Normal death by shading is not counted.
Foliage transparency
A measure of sunlight (%) filtering through needles and leaves in the crown.

Figure 2. Three crown-rating indicators: crown density, crown dieback, and foliage transparency.

Damage

Pathogens, insects, air pollution, and other natural or human disturbances all cause damage and can adversely affect the health of the tree and ultimately the forest. The FHM program collects data on up to three instances of damage per tree, limiting observations to certain types of damage, which may potentially kill or adversely affect the trees long-term survival. For each tree the location and an assessment of the degree of severity are also recorded. Types of damage include; cankers, conks, open wounds, resinosis, dead tops/loss of apical dominance, broken limbs, branches and roots, brooms, damaged foliage, and discolored foliage.

Air Pollution

The effects of air pollution on forest ecosystems are evaluated regionally in the FHM program in three ways: ozone bioindicator plant evaluation; lichen community analysis focusing on sulfur and nitrogen sensitive species; and soil chemistry analysis evaluating soil pH and exchangeable Ca, Mg, and K. Currently, the implementation of the ozone bioindicators in the east and the Lake States is well developed; implementation of lichen and soils chemistry indicators has been done in limited areas and will be done in Wisconsin in 1998.

Ozone Bioindicator Monitoring

Ozone bioindicator plants are vascular plant species (herbs, shrubs, or trees) that are highly sensitive to ozone air pollution and respond with distinct foliar injury symptoms that can be diagnosed under field conditions. Ozone bioindicator plants are evaluated on or near the FHM plots in suitable openings (>0.5 acre) where the appropriate ozone-sensitive plant species are found. Plots are scored as positive or negative for ozone injury. The severity of ozone injury at each plot is also recorded.

Lichen Monitoring

Lichens are fungi that live in intimate association with algae. Lichens are very responsive to environmental stressors in forests, including changes in forest structure, air quality, and climate. In FHM data is collected on epiphytic lichens, those growing on trees and shrubs. Because the effects of air pollutants on trees can be difficult to separate from other influences on growth, epiphytic lichens provide a clear indication of potential air quality impacts on total forest productivity.

Lichen community measurements are made within a 120-foot-radius circle centered on each FHM field plot. Additional data can be collected from urban and industrial sites to help define lichen community response to air pollution in each region. FHM crews are trained to collect a sample of each species found and record the relative abundance of each species. Lichen experts do the actual species identification.

Soil Chemistry

Soil morphology (physical characteristics) and chemistry indicators of ecological condition used in FHM to evaluate the below-ground portion of forest ecosystems. Measurements will be made of A, E, B, or C mineral horizons as deep as 40 inches from the soil surface, including any overlying O horizon (organic horizon) and forest floor deposits. Soils will be collected on the forested plots scheduled for sampling in 1998.

1996 FHM Plot Activities and Highlights

There were few changes to the FHM program in 1996. In 1995, the base grid was split into four sub-grids and one sub-grid with one-third of the previous year's plots were evaluated in 1996 for a total of 76 plots. Of these plots 27 were forested (Table 1, Figure 3).

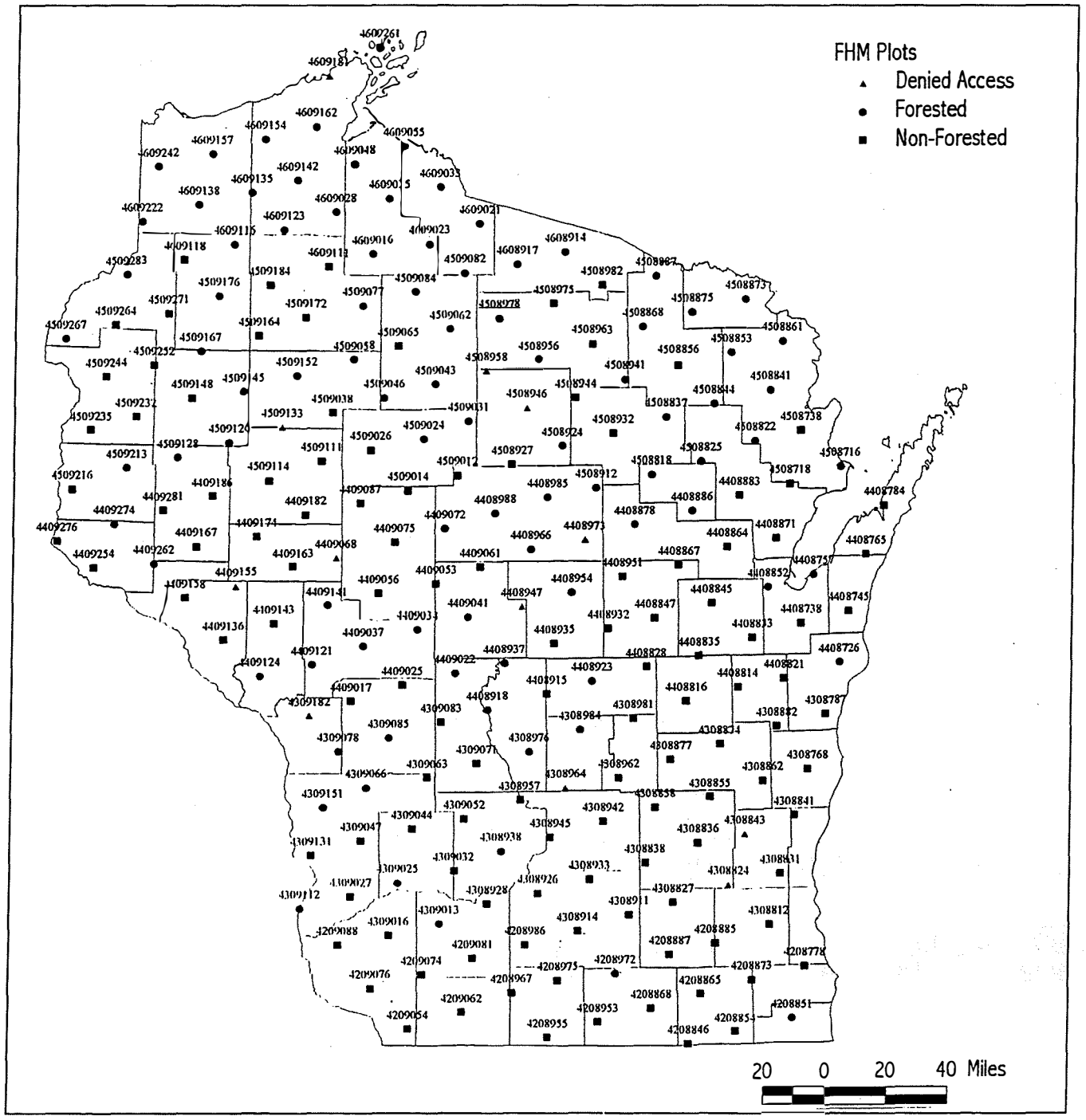

Figure 3. All FHM plots by status in Wisconsin, 1996.

Table 1. Number of plots evaluated in 1996 in Wisconsin, and the associated land use class.

	Total Plots	Forest	Urban	Crop	Pasture	Range	Farm	Marsh	Water	Other
WI	76	35.9	12.8	29.7	2.6	0.3	6.3	2.9	5.0	2.8

Table 2. Forest types on Wisconsin plots according to FHM, 1996

Forest Type	Percent of Forested Plots
White/Red/Jack Pine	18.5
Spruce/Fir	12.8
Oak/Pine	4.6
Oak/Hickory	9.8
Elm/Ash/Red Maple	7.3
Maple/Beech/Birch	25.6
Aspen/Birch	21.3

Table 3. Distribution of live trees of major species on FHM plots in the Lake States, by foliage transparency class, 1996

		Foliage Transparency Class		
Species	N	Normal (0-30%)	Moderate (31-50%)	Severe (51+%)
All species	4,452	97.3	2.3	0.4
Softwoods	1,312	97.8	2.2	0.0
Hardwoods	3,140	97.1	2.3	0.6

Table 4. Distribution of live trees of major species on FHM plots in the Lake States, by crown density class, 1996

		Crown Density Class		
Species	N	Good (51+%)	Average (21-50%)	Poor (1-20%)
All species	4,452	54.7	43.4	1.9
Softwoods	1,312	50.0	48.5	1.5
Hardwoods	3,140	54.7	43.4	1.9

Table 5. Distribution of live trees of major species on FHM plots in the Lake States, by crown dieback class, 1996

		Crown Dieback Class			
Species	N	None (0-5%)	Light (6-20%)	Moderate (21-50%)	Severe (51+%)
All species	4,452	85.2	12.5	1.1	1.2
Softwoods	1,312	86.6	11.0	1.7	0.7
Hardwoods	3,140	84.6	13.2	0.9	1.3

Conclusions and Future Direction for FHM program in Wisconsin

In the beginning of this report, forest health monitoring was defined as a long-term program to determine base line or current conditions of forest ecosystems, and detect changes and trends over time. The plot and survey component of the program have proved useful in determining forest health. Wisconsin, Michigan, and Minnesota now have a four-year baseline of forest health monitoring plot data. Although the FHM program can not draw conclusive conclusions for Wisconsin alone, forest health monitoring data indicates that the Lake States forests, including Wisconsin are generally in good health.